COST STUDIES OF MULTIPURPOSE LARGE LAUNCH VEHICLES

VOLUME III

RESOURCE IMPLICATIONS

FINAL REPORT

SEPTEMBER 15, 1969

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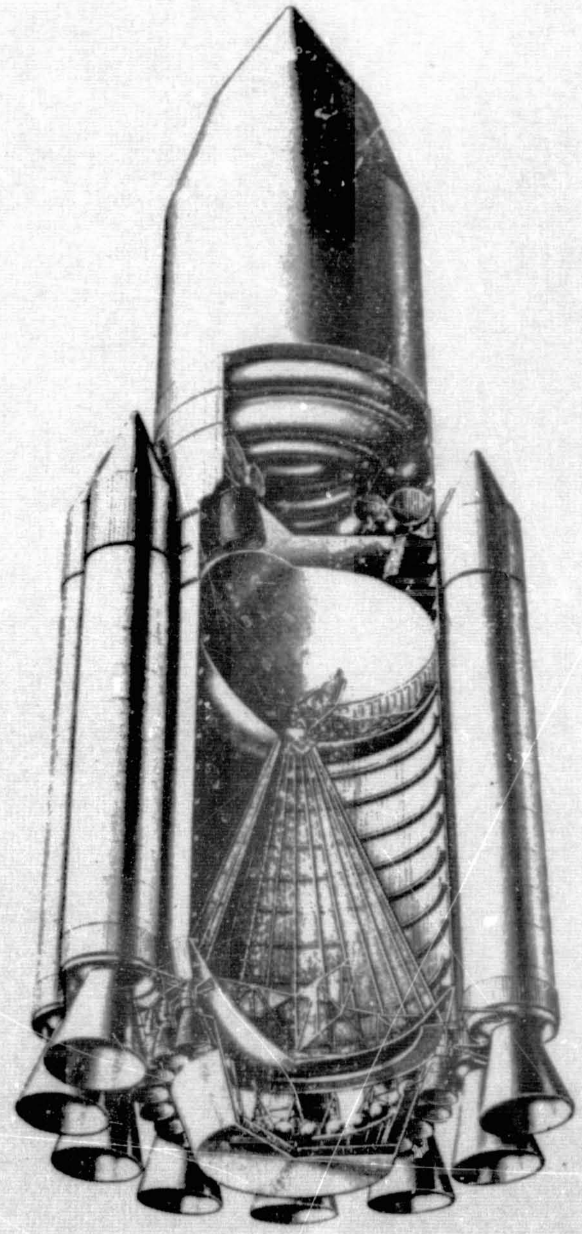

PREPARED UNDER CONTRACT
NAS 2-5056

BY THE BOEING COMPANY
AEROSPACE GROUP
SOUTHEAST DIVISION

(BOEING DOCUMENT NO.
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FINAL REPORT
FOR
COST STUDIES OF MULTIPURPOSE LARGE LAUNCH VEHICLES

VOLUME III
RESOURCE IMPLICATIONS

PREPARED UNDER CONTRACT NAS2-5056
FOR
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
OFFICE OF ADVANCE RESEARCH AND TECHNOLOGY
MISSION ANALYSIS DIVISION
SEPTEMBER 15, 1969

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ABSTRACT

Nine volumes including this volume present the final report documentation outlining the accomplishments for the "Cost Studies of the Multipurpose Large Launch Vehicles" (MLLV), NASA/OART Contract NAS2-5056. This volume defines the resources necessary for implementation and operation of either the Advanced Multipurpose Large Launch Vehicle (AMLLV) or the Multipurpose Large Launch Vehicle (MLLV). These resource implications were determined to support the cost analyses.

The MLLV family will consist of a single-stage-to-orbit configuration plus other configurations consisting of a main stage (as used for the single-stage-to-orbit configuration) with various quantities of 260 inch diameter solid rocket motor (SRM) strap-on stages and/or injection stage modules. The main stage will employ LOX/LH_2 propellant with either a multichamber/plug or toroidal/aerospike engine system. The single-stage-to-orbit configuration will have a payload capability of approximately 500,000 pounds to a 100 nautical mile earth orbit. With the addition of the strap-on SRM stages and/or LOX/LH_2 injection stage modules, this payload capability can be increased incrementally to as much as 1,850,000 pounds.

The contract consisted of four study phases. The Phase I activity was a detailed cost analysis of an Advanced Multipurpose Large Launch Vehicle (AMLLV) family as previously defined in NASA/OART Contract NAS2-4079. Costs for vehicle design, test, transportation, manufacture and launch were defined. Resource implications for the AMLLV configurations were determined to support the cost analysis.

The Phase II study activity consisted of the conceptual design and resource analysis of a smaller or half size Multipurpose Large Launch Vehicle (MLLV) family.

The Phase III activity consisted of a detailed cost analysis of the smaller Multipurpose Large Launch Vehicle configurations as defined in Phase II. Costs for vehicle design, test, transportation, manufacture and launch were determined.

The Phase IV activity assessed the results of the study including the implications on performance, resources and cost of vehicle size, program options, and vehicle configuration options. The study results provided data in sufficient depth to permit analysis of the cost/performance potential of the various options and/or advanced technologies.

ABSTRACT (Continued)

LIST OF KEY WORDS

Advanced Multipurpose Large Launch Vehicles (AMLLV)

Half Size Multipurpose Large Launch Vehicles (MLLV)

Single-Stage-to-Orbit

Multichamber/Plug Engine System

Toroidal/Aerospike Engine System

260 Inch Solid Propellant Rocket Motor (SRM)

Orbital Injection Stage

Contract NAS2-4079

Contract NAS2-5056

Payload to 100 NM Orbit

Performance

Conceptual Design

Zero Stage Vehicles

Parallel Stage Vehicles

Main Stage Throttling

FOREWORD

This volume, Advanced Technology Implications, is one of nine volumes documenting the results of a twelve month study program "Cost Studies of Multipurpose Large Launch Vehicles", NASA/OART Contract NAS2-5056. The objective of this study was to define cost, cost sensitivites, and cost/size sensitivites of potential future launch vehicles to aid in the guidance of current and future technology programs. The baseline vehicles utilized to make this assessment were:

1. The Advanced Multipurpose Large Launch Vehicles (AMLLV) as defined under NASA/OART Contract NAS2-4079.

2. The Multipurpose Large Launch Vehicles (MLLV) as defined under this contract and described in Volume II, "Half Size Vehicle (MLLV) Conceptual Design".

The program documentation includes this volume (Resource Implications), a Summary Volume plus an Advanced Technology Implications Volume, a Design Volume, Cost Volumes, Cost Implications Volume, and Appendices Volumes. Individual designations for these volumes are as follows:

Volume I	Summary
Volume II	Half Size Vehicle (MLLV) Conceptual Design
Volume III	Resource Implications
Volume IV	Baseline AMLLV Costs
Volume V	Baseline MLLV Costs
Volume VI	Cost Implications of Vehicle Size, Technology Configurations, and Program Options
Volume VII	Advanced Technology Implications
Volume VIII	Flight Control and Separation, and Stress Analysis (Unclassified Appendices)
Volume IX	Propulsion Data and Trajectories (Classified Appendices)

FOREWORD (Continued)

Data on the 260 inch diameter solid propellant rocket motor were obtained from the Aerojet General Corporation. Data on the multichamber/plug propulsion system were obtained from the Pratt and Whitney Division of the United Aircraft Corporation and the Rocketdyne Division of the North American Rockwell Corporation. Data on the toroidal/aerospike propulsion system were obtained from the Rocketdyne Division of the North American Rockwell Corporation.

These propulsion data were obtained from the propulsion contractors at no cost to the contract. The material received encompassed not only the technical data, but costs, resources, schedules and advanced technology information. This support materially aided The Boeing Company in the preparation of a complete and meaningful study and is gratefully acknowledged.

This study was administered under the direction of NASA/OART Mission Analysis Division, Ames Research Center, Moffett Field, California under the direction of the technical monitor, Mr. Edward W. Gomersall.

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1.0 INTRODUCTION AND SUMMARY

The resources necessary to define the costs for implementation and operation of both the AMLLV and MLLV families are defined in the following plans which constitute this document:

a. Design Plan (Section 3.0)

b. Development and Test Plan (Section 4.0)

c. Manufacturing Plan (Section 5.0)

d. Transportation Plan (Section 6.0)

e. Launch Operations Plan (Section 7.0)

f. Schedule Plan (Section 8.0)

g. Resource Requirements for Design Alternatives (Section 9.0)

For each plan, there are descriptions, assumptions and guidelines upon which the plans were developed. Figure 1.0.0.0-1 illustrates the sources and flow of AMLLV/MLLV cost inputs.

To accomplish the objective of providing "modularized" detail costs of the two vehicle families, costs (and supporting resource data) were categorized for three program phases as follows:

"A" "Get Ready" Phase

This category includes non-recurring resource requirements for vehicle design, and for the tooling, equipment and facilities required to produce and launch a vehicle.

"B" Development Test Phase

This category includes the non-recurring resource requirements for all development test activity required to develop the launch vehicle, its components and the associated support hardware.

"C" The Operational Program Phase

This category includes all of the recurring resource requirements for manufacture and launch of the operational vehicles.

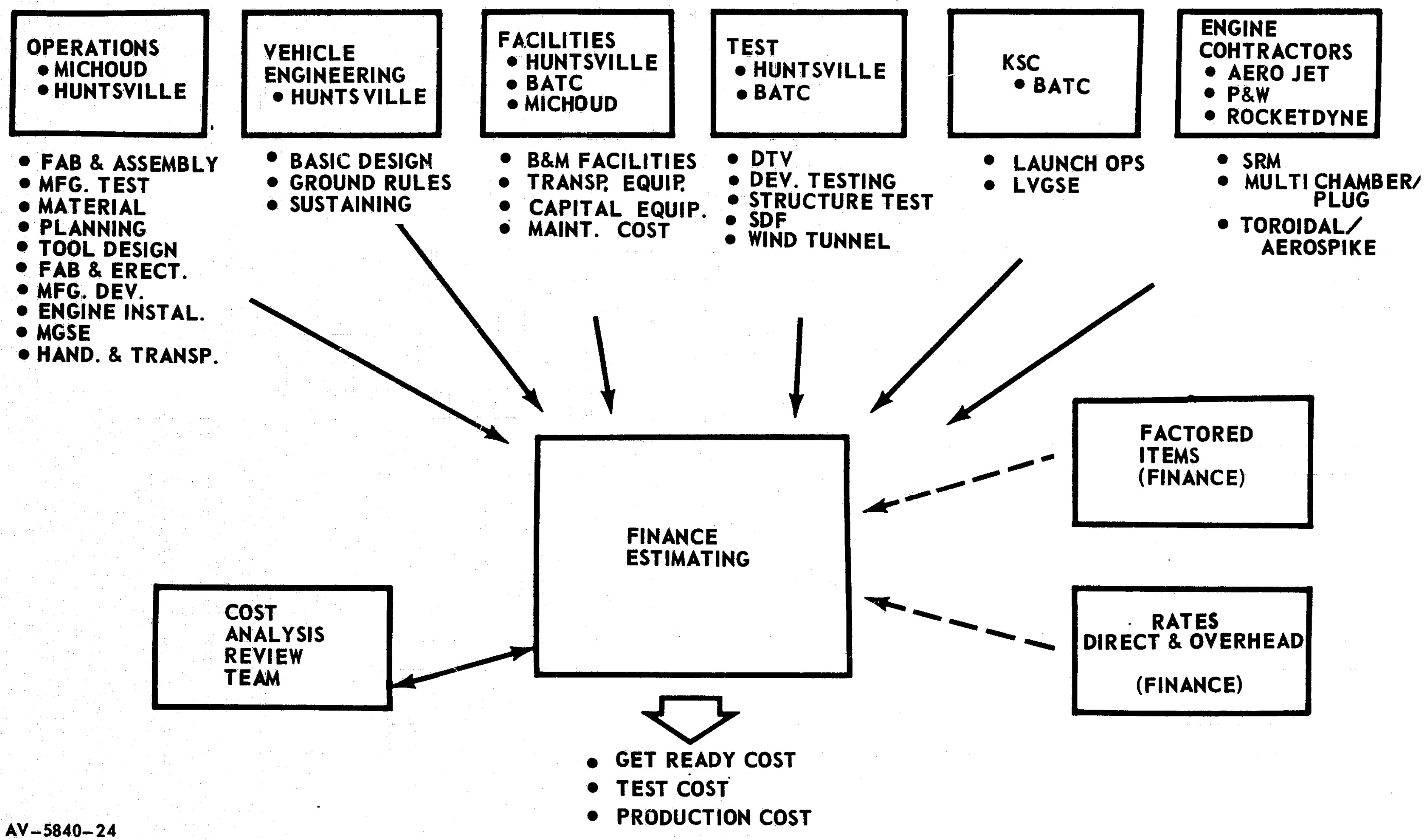


FIGURE 1.0.0.0-1 AMLLV/MLLV COST INPUTS RECURRING AND NON-RECURRING

1.0 (Continued)

Resource requirements for each of the above phases were estimated in terms of:

a. Direct manhours

   1. Engineering

   2. Non-Engineering

b. Facilities

c. Capital equipment

d. Tooling

e. Materials

The basic resource requirements were defined by the various Boeing operational groups which are performing related tasks for the Saturn V/S-IC Programs (Boeing/Huntsville, Boeing/Michoud and Boeing Atlantic Test Center at Cape Kennedy). These inputs provided the basis for estimating the program cost. Industry wide labor rates and factors were applied for indirect labor and management cost. These rates and factors were based on either historical data or current negotiated procedures for the Saturn V/S-IC Program. The final calculated costs are presented in Volumes IV and V of this final report.

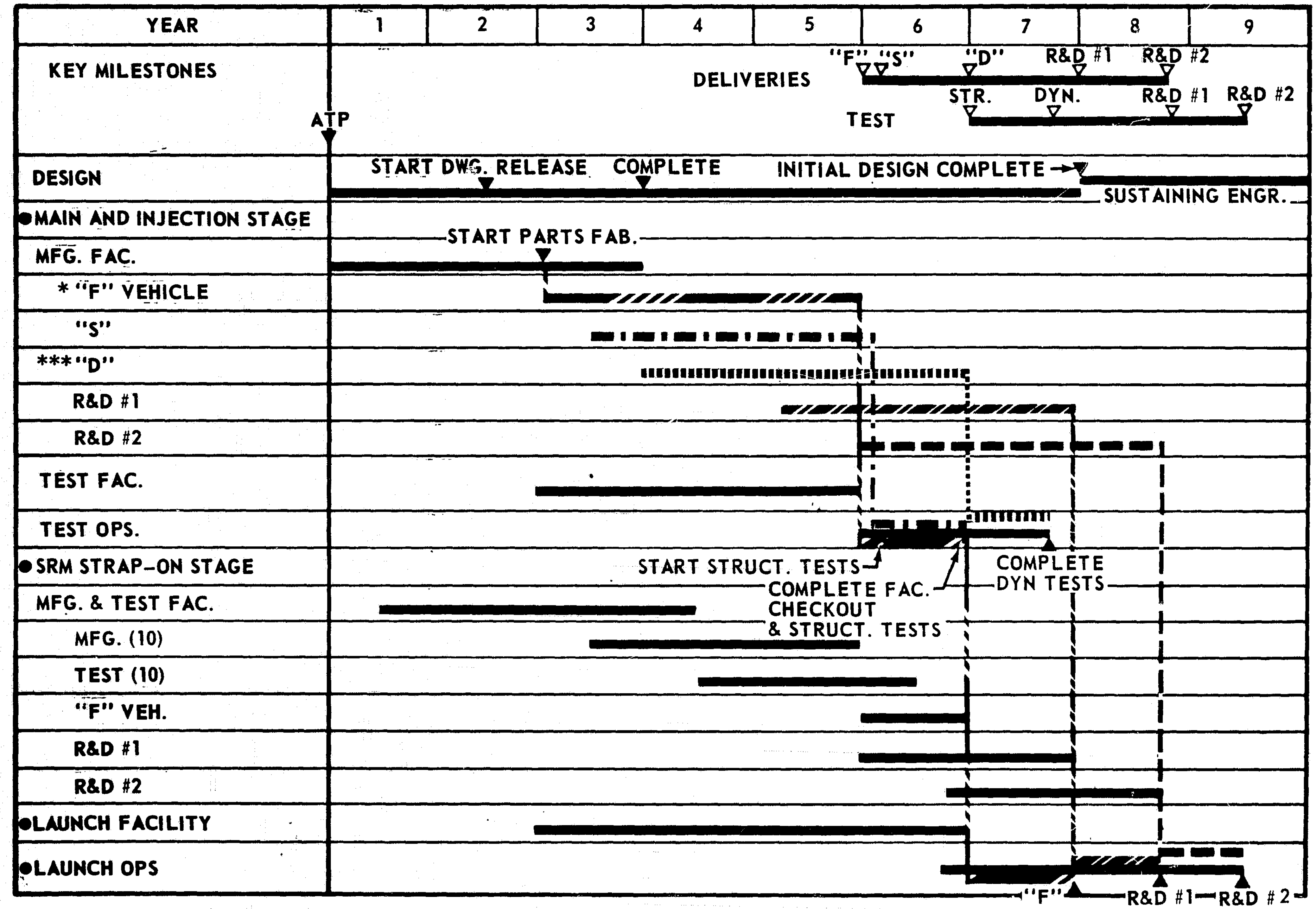
Inputs on liquid engine costs were provided by Pratt and Whitney and Rocketdyne. Solid rocket motor costs were provided by Aerojet General Corporation.

The guidelines and assumptions used in the resources implications portion of the study were developed from the contractual requirements, the previous AMLLV study (NAS2-4079), and applicable data from previous and current studies. Where special circumstances dictated an arbitrary assumption, The Boeing Company and the NASA technical monitor concurred on a suitable guideline, i.e., to aid in costing, etc., manufacturing was assigned to take place at Michoud; the launch site would be land based rather than occupy an offshore location, etc.

Figure 1.0.0.0-2, Master Program Schedule, provided for reference in this summary, shows the relationship of each of the resource plans discussed below.

1.1 DESIGN PLAN

The design plan defines the engineering requirements for initial design, R&D support and sustaining engineering during production and launch. Resource requirements for the engineering design activity will be limited to manpower requirements. Adequate facilities and equipment are considered to be available at the Michoud site.



*"F" - Facilities **"S" - Static Test ***"D" - Dynamic Test

FIGURE 1.0.0.0-2 MASTER PROGRAM SCHEDULE

1.1 (Continued)

Engineering design manpower does not appear to be proportional to vehicle size or weight. Complexity of vehicle systems appears to be the parameter that best determines the required design effort. Estimates of stage complexity can be made by comparing system operational life, number of systems, effects of a system failure, number of functions performed by the system and whether its design is, or is not within the present stage-of-the-art.

Release of component drawings will be initiated 1 1/2 years after authorization to proceed. The drawings will be revised based upon the results of the R&D test. Sustaining engineering will commence at the beginning of the 8th year and continue throughout the remainder of the production and launch program.

The design engineering manhours, exclusive of support of the development test program and sustaining engineering, (for "A" costs) are shown below:

STAGE	AMLLV	MLLV
Main Stage	3,420,000	3,345,000
Injection Stage Engine Module	2,070,000	2,070,000
Injection Stage Fuel Module	45,000	45,000
SRM Stage	220,000	160,000

The sustaining engineering manhour estimates (for "C" Costs) are shown below:

STAGE	AMLLV	MLLV
Main Stage	447,000	447,000
Injection Stage Engine Module	145,000	145,000
Injection Stage Fuel Module	4,500	4,500
SRM Stage	28,500	28,500

Engineering support requirements for the development test program are included in the resource requirements for the R&D test plan.

1.2 DEVELOPMENT AND TEST PLAN (NON-RECURRING AND RECURRING TESTS)

The Development and Test Plan defined the non-recurring R&D and the recurring acceptance, static firing and pre-launch test activities. The R&D tests identified and the associated costs for four different programs are shown in Table 1.2.0.0-I. The four programs for which costs are shown are:

a. Development of an AMLLV Single-Stage-to-Orbit Vehicle.

b. Development of an AMLLV Maximum Payload Vehicle consisting of a Main Stage, 12 strap-on stages and a three module injection stage.

c. Development of an MLLV Single Stage to Orbit Vehicle.

d. Development of an MLLV Maximum Payload Vehicle consisting of a Main Stage, 8 strap-on stages and a three module injection stage.

Manufacturing mockup tests will consist of building a mockup vehicle for use in initial manufacturing facility layout, evaluating procedures, and for training of manufacturing personnel. The manufacturing mockup plus structural components of the Facilities Checkout (F) vehicle, discussed below, will basically include all of the components of a complete launch vehicle system exclusive of operational liquid engines. The manufacturing resources attributable to these tests were the manpower and material required to fabricate the mockup component elements, and for assembly of these elements into the mockup vehicle. Adequate tooling, equipment and facilities will exist except for the floor space that the mockup will occupy.

A facility checkout vehicle will be provided to conduct the tooling, GSE and facility shakedown test. This "F" vehicle will consist of a main stage, a single module injection stage, a single SRM strap-on stage loaded with inert propellant, and a mockup payload with a simulated instrument unit. These stages of the "F" vehicle will consist of load carrying structure, and those elements which will interface with other stages or GSE. Resource requirements for fabrication of the "F" vehicle were determined by defining the specific components that will make up the "F" vehicle and summing the manpower and material required to fabricate and assemble these components. Adequate tooling, equipment and facilities will exist. The "F" vehicle will be used to check out the dynamic test facilities. Resource requirements for use of the "F" vehicle at the dynamic test facility were attributed to the requirements for dynamic test rather than the "F" vehicle, because if there were no dynamic test there would be no requirement for this "F" vehicle operation. Resource requirements attributable to use of the "F" vehicle during transportation and at the launch site were generally assumed to be the same as those attributable to processing the first flight test vehicle.

TABLE 1.2.0.0-I Development and Test Plan Cost Summary

TEST	AMLLV		MLLV	
	Single-Stage to Orbit	Maximum Vehicle	Single-Stage to-Orbit	Maximum Vehicle
	(DOLLARS IN THOUSANDS)			
a. R&D Tests (Non-Recurring) "B" Cost Category				
1. Model	600	1,000	600	1,000
2. Manufacturing Mock-Up	5,038	6,296	3,176	3,969
3. Facility, GSE, & Tooling Shakedown	319,288	417,440	287,536	369,193
4. Component and Sub-Systems	150,000	209,684	120,000	173,037
5. Breadboard	80,520	98,528	73,200	89,566
6. Structural (Static Load)	86,067	130,869	66,420	96,995
7. Dynamic	66,057	125,511	53,104	97,874
8. Engine Development and Qualification	492,943	733,686	325,471	484,943
9. SRM Development and Qualification		137,768		117,116
10. Static Firing and Flight Tests	836,735	1,284,247	731,826	1,026,726
11. Ground Support Equipment (GSE) and Launch Vehicle Ground Support Equipment (LVGSE)	GSE and LVGSE costs are included in the equipment costs at the manufacturing, test and launch facilities, and in vendor procurement costs.			
b. Manufacturing and Operations Tests (Recurring) 1. General Acceptance 2. Static Firing 3. Pre-Launch Test and Checkout	Recurring Test Costs are included in the Manufacturing and Launch Operations Estimates for the "C" Cost Category.			

1.2 (Continued)

The component and subsystems test program will consist of those development and qualification tests required for vehicle components and subsystems (including purchased or procured items) exclusive of the liquid engine systems and the solid rocket motors. The resource requirements for this series of tests were obtained using factors determined from the current Saturn V/S-IC program. No additional facility requirements were attributed to this series of tests.

A systems development breadboard was specified for this program. This breadboard will be used as a tool to assist the design engineer during the initial design phase to evaluate component and subsystem interactions and compatibility. The breadboard will be updated as changes are made to the design, and after completion of the development test program will be subsequently maintained to assist in the evaluation of later design changes and/or specific mission requirements. The resource requirements for this test assume that existing facilities are adequate but that a new computer will be required.

Each element of the load-carrying structure will be subjected to a structural load test to failure. In excess of a complete set of load carrying flight type structures, additional structural components will be required to support this test program. New test facilities for these tests will be required adjacent to the manufacturing site and at the SRM subcontractor's facility.

Although no specific requirement for a dynamic test program was identified, in accordance with the Saturn V/S-IC test philosophy a dynamic test program was specified. Dynamic tests will be conducted on the main stage and on the injection stage. SRM stages will not be provided but their interactions will be simulated during the dynamic test by providing programmed inputs to hydrodynamic shakers located at the SRM stage attach points to the vehicle. A new facility adjacent to the main stage manufacturing facility will be required for these tests. Incorporation of these tests into the R&D program increased the total time span for the R&D program by one year. Elimination of these tests, therefore, would result in a one year reduction in the R&D test program time span and also would reduce the overall R&D program costs by approximately $125,511,000 for the AMLLV, or $97,874,000 for the half size MLLV.

The liquid engine systems for the main stage and injection stage will require a development and qualification program. The magnitude of the main stage engine program will be dependent upon the type of engine system used (i.e., the multichamber/plug or the toroidal/aerospike).

The baseline program defines the resource requirements for the Pratt and Whitney multichamber/plug engine system. Backup data shows the development and qualification requirements for the Rocketdyne toroidal/aerospike engine systems. No new

1.2 (Continued)

engine test facilities will be required as the engine systems will be tested by individual module. The first complete test of the assembled main stage engine system will occur at the first static firing of the main stage as discussed in a subsequent paragraph.

The TVC system for the multichamber/plug engine system consists of actuators which gimbal the different engine chambers to provide the lateral thrust vector. The lateral reactions from this type of system can be analytically determined with reasonable accuracy. The toroidal/aerospike engine system, however, will use injection of liquid oxygen about the base of the plug to provide the necessary lateral force. This type of engine system is dependent upon specific configuration layouts and is sensitive to altitude effects. Anticipated lateral reactions as a function of injectant flow are difficult to determine analytically for the overall flight regime. As no test facility is provided for conducting tests of the full scale engine system and its associated TVC (and in particular over the altitude range that will be encountered in flight) the first operational test of the thrust vector control system will be in conjunction with the first R&D flight test. Design of these systems therefore must rely on extensive model tests and analytical studies to assure successful operation during the initial flight test.

The SRM stage development and qualification tests will consist of ten firings of the full size solid rocket motor. Four of these firings will be for development of the solid rocket motor and the remaining six for qualification. Three of these latter tests will also incorporate the additional hardware elements that will make up the solid rocket motor stage, i.e., forward and aft attachment hardware, destruct system, instrumentation, etc. The SRM TVC system will be on each of the ten motors tested such that its development and qualification will be accomplished concurrent with the firing tests. These SRM tests will be accomplished using the facilities, tooling and equipment to be provided for the follow-on production phase and will not, therefore, require additional resources other than manpower, material and instrumentation.

In accordance with current test philosophy, two R&D flight vehicles will be required in the development test program. By ground rules, the R&D flight configuration will be the maximum size configuration anticipated for the program, i.e., the main stage plus the three module injection stage plus a full complement of strap-on stages. The liquid stages for these flight vehicles will be static tested prior to flight. The resource requirements for the first static firing and flight test were assumed to be equivalent to those of the first production unit for cost estimating (Considering the learning curve effects, the first operational vehicle will then be the third unit down the learning curve, i.e., the two R&D flight tests being the first two units).

1.2 (Continued)

Certain other tests will be required to develop and qualify the ground support equipment and the launch vehicle ground support equipment (LVGSE). The resource requirements for these tests were attributed to the cost of procuring this hardware.

The total time span of the R&D program (from authorization to proceed through launch of the 2nd R&D flight test) will cover a period of 8 1/2 years.

1.3 MANUFACTURING PLAN

The manufacturing plans for the main stage, injection stage and SRM strap-on stage attachment hardware were developed in detail in order to define resource requirements. In addition to data for these elements which will be fabricated and assembled at the Mfg. Facility, detail data for purchased items (main and injection stage liquid engines and solid rocket motors) were supplied by Pratt and Whitney, Rocketdyne, and Aerojet General Corporation.

The plans are, where practicable, an extrapolation of fabrication techniques developed for the S-IC stage. The plans describe the fabrication and assembly of components, sub-assemblies, systems and final assembly of each stage.

Procedures for fabrication and assembly are presented for each major structural component, and finally, for assembly of these components into a complete stage. Included are tooling lists and pictures, capital equipment lists and facilities requirements in terms of square footage. Pictorial flow sequences of assembly operations from sub-assembly through final assembly are presented. Table 1.3.0.0-I summarizes resource requirements. "B" category estimates are not included as this summary is concerned with "get ready" and operating costs for manufacturing, transportation and launch.

1.3.1 Main Stage

The main stage structure is composed of six major sub-assemblies; the interchangeable forward skirt, LOX tank, LH_2 tank, thrust structure, base plug and tunnels. The fabrication and assembly sequence is essentially the same for both versions of the interchangeable forward skirt assemblies. Main stage systems include the propulsion/mechanical, electrical/electronics, instrumentation and flight control systems. The main stage engines are received from the propulsion contractor as a sub-assembly, tested and installed onto the main stage assembly.

Figures 1.3.1.0-1 and 1.3.1.0-2 summarize the main stage manufacturing plan by showing the final assembly sequence and the flow through the manufacturing facility.

The estimates provided to Finance for costing and summarized in Table 1.3.1.0-I included:

TABLE 1.3.0.0-I MANUFACTURING RESOURCE REQUIREMENTS SUMMARY - AMLLV AND MLLV

CATEGORY "A" & "C"	MAIN STAGE		I/S - ENGINE MODULE		I/S - FUEL MODULE		SRM STAGE	
	AMLLV	MLLV	AMLLV	MLLV	AMLLV	MLLV	AMLLV	MLLV
MANUFACTURING MANHOURS (NON-RECURRING)	(1) 23,992,081 (2) 25,620,245	(1) 15,775,723 (2) 16,801,642	4,749,580	3,125,479	(SAME FOR 1, 2 OR 3 MODULES)		3,277,000	3,105,000
MANUFACTURING MANHOURS (RECURRING)	(1) 2,309,842 (2) 2,473,365	(1) 1,992,865 (2) 2,096,363	486,201	382,852	(3) 313,551	(3) 230,810	379,168	310,000
MANUFACTURING MATERIALS (RECURRING)	(1) $33,105,108 (2) $33,342,622	(1) $27,987,570 (2) $28,128,191	$2,047,000	$1,520,000	$1,114,000	$848,000	$7,120,940	$5,537,314
MFG. MTLS. - (NON-RECURRING)	$8,363,173	$5,051,358	$1,003,580	$1,003,580	——	——	$3,079,000	$2,920,000
TOOLING MATERIALS (4) (NON-RECURRING)	(1) $29,942,050 (2) $31,533,640	(1) $21,957,865 (2) $22,960,567	$6,045,786	$4,180,188	——	——	$61,480,132	(*) $44,550,774
TOOLING MANHOURS (4) (NON-RECURRING)	(1) 14,320,976 (2) 15,230,456	(1) 9,407,795 (2) 9,980,768	3,141,774	2,033,265	——	——	*THESE DOLLARS INCLUDE SRM TOOLING MATERIAL AND TOOLING MANHOUR COSTS	
CAPITAL EQUIPMENT (NON-RECURRING)	$48,822,000	$46,346,000	$12,260,000	$15,449,000	——	——	——	——
CAPITAL EQUIPMENT (RECURRING)	$2,203,000	$2,089,000	$736,000	$700,000	——	——	——	——
FACILITIES (NON-RECURRING)	$113,324,000	$102,431,000	$37,781,000	$34,144,000	——	——	(5) $73,381,000	(5) $50,604,000
FACILITIES (RECURRING)	$5,941,000	$5,679,000	$1,975,000	$1,893,000	——	——	$7,933,000	$6,304,000
ENGINE FACILITY (NON-RECURRING)	$27,850,000	$27,850,000	——	——	——	——	——	——
ENGINE FACILITY (RECURRING)	$1,795,000	$1,795,000	——	——	——	——	——	——

NOTES:

(1) STANDARD FORWARD SKIRT
(2) ALTERNATE FORWARD SKIRT
(3) INCLUDES ENGINE MODULE - 2 ENGINES W/SYSTEMS COSTS PRORATED
(4) INCLUDES MGSE
(5) INCLUDES EQUIPMENT COSTS

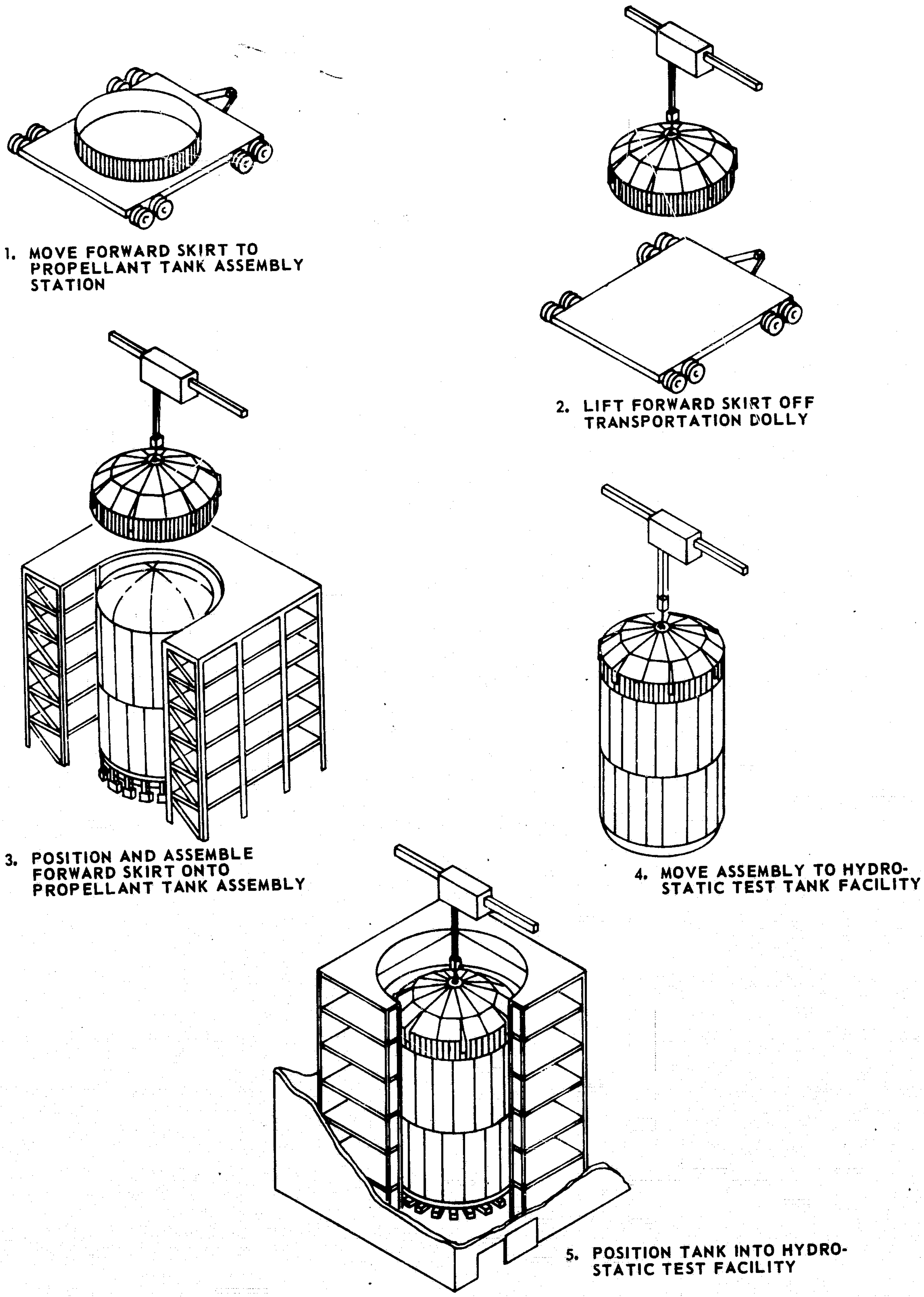
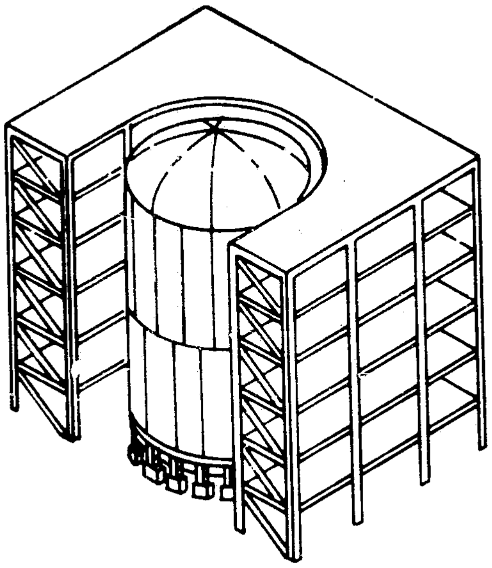
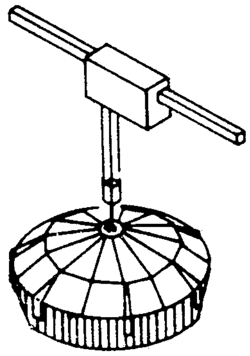


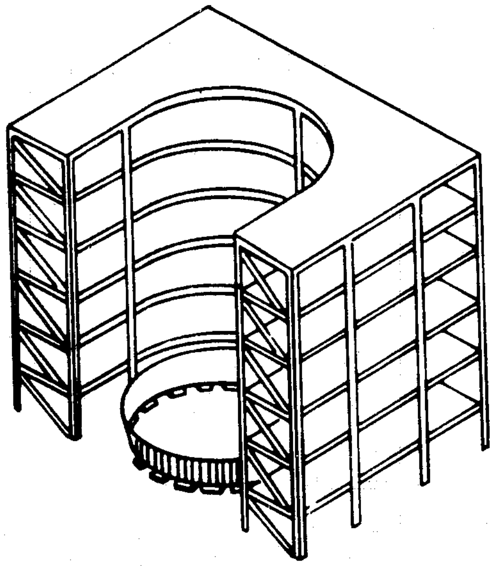
FIGURE 1.3.1.0-1 COMPLETE MANUFACTURING SEQUENCE, ADVANCED MULTIPURPOSE LARGE LAUNCH VEHICLE (SHEET 1 OF 3)



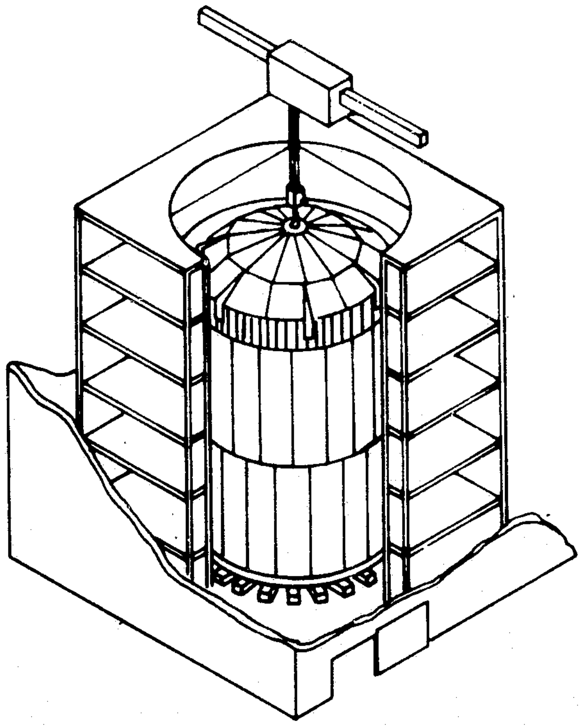
6. CLEAN AND HYDROSTATIC TEST TANKS



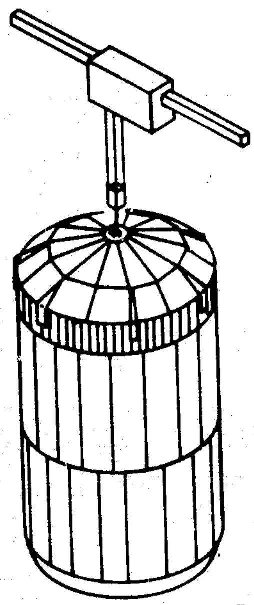
7. MOVE AFT SKIRT ASSEMBLY TO PROPELLANT TANK ASSEMBLY STATION



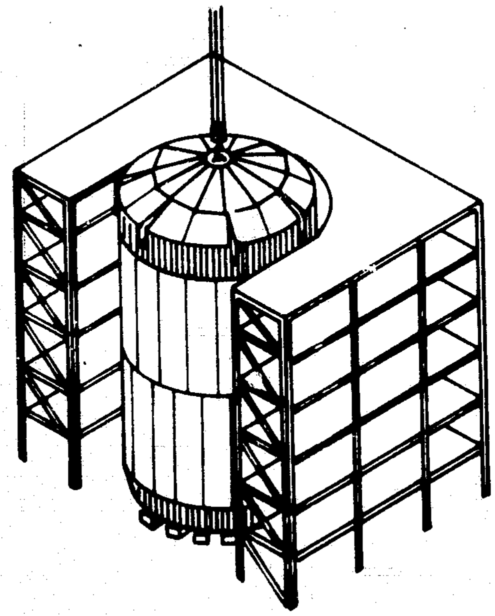
8. POSITION AFT SKIRT IN ASSEMBLY TOWER



9. REMOVE PROPELLANT TANK ASSEMBLY FROM HYDROSTATIC TEST FACILITY

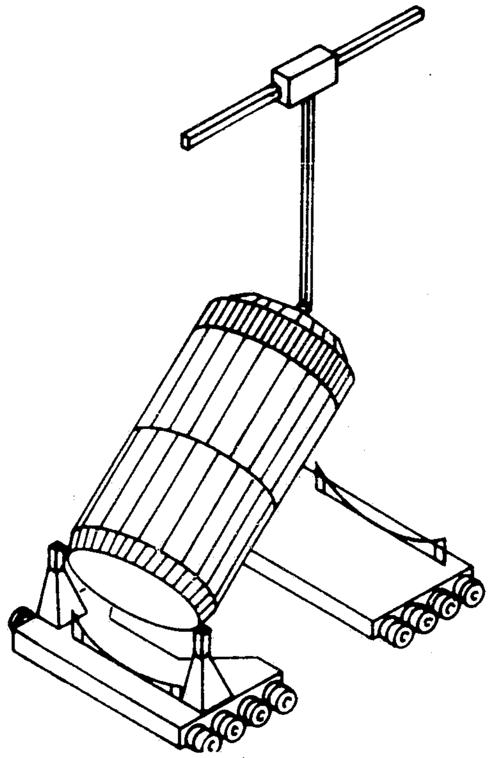


10. TRANSPORT PROPELLANT TANK FROM HYDROSTATIC TOWER TO TANK ASSEMBLY STATION

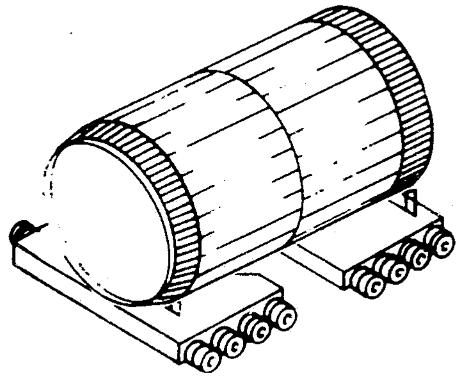


11. POSITION PROPELLANT TANK ON AFT SKIRT ASSEMBLY AND MECHANICALLY FASTEN

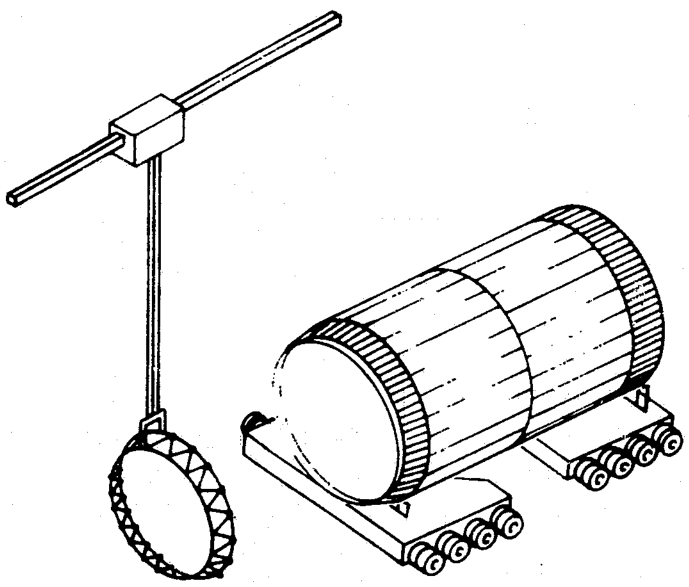
FIGURE 1.3.1.0-1 (SHEET 2 OF 3)



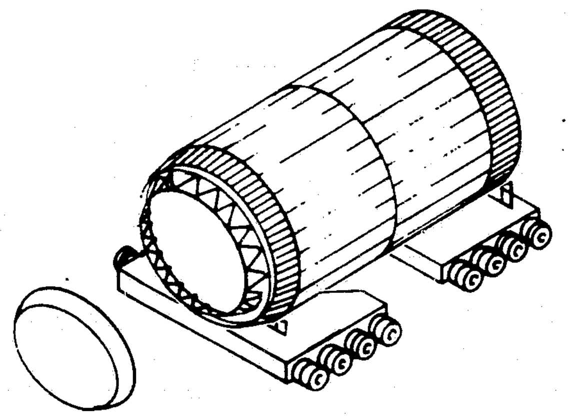
12. LOWER STAGE ONTO TRANSPORTER



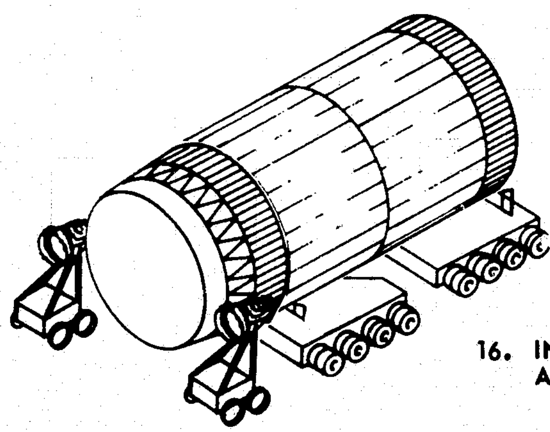
13. STAGE NESTLED ON TRANSPORTER



14. ASSEMBLE TUBULAR TRUSSWORK
TO AFT SKIRT

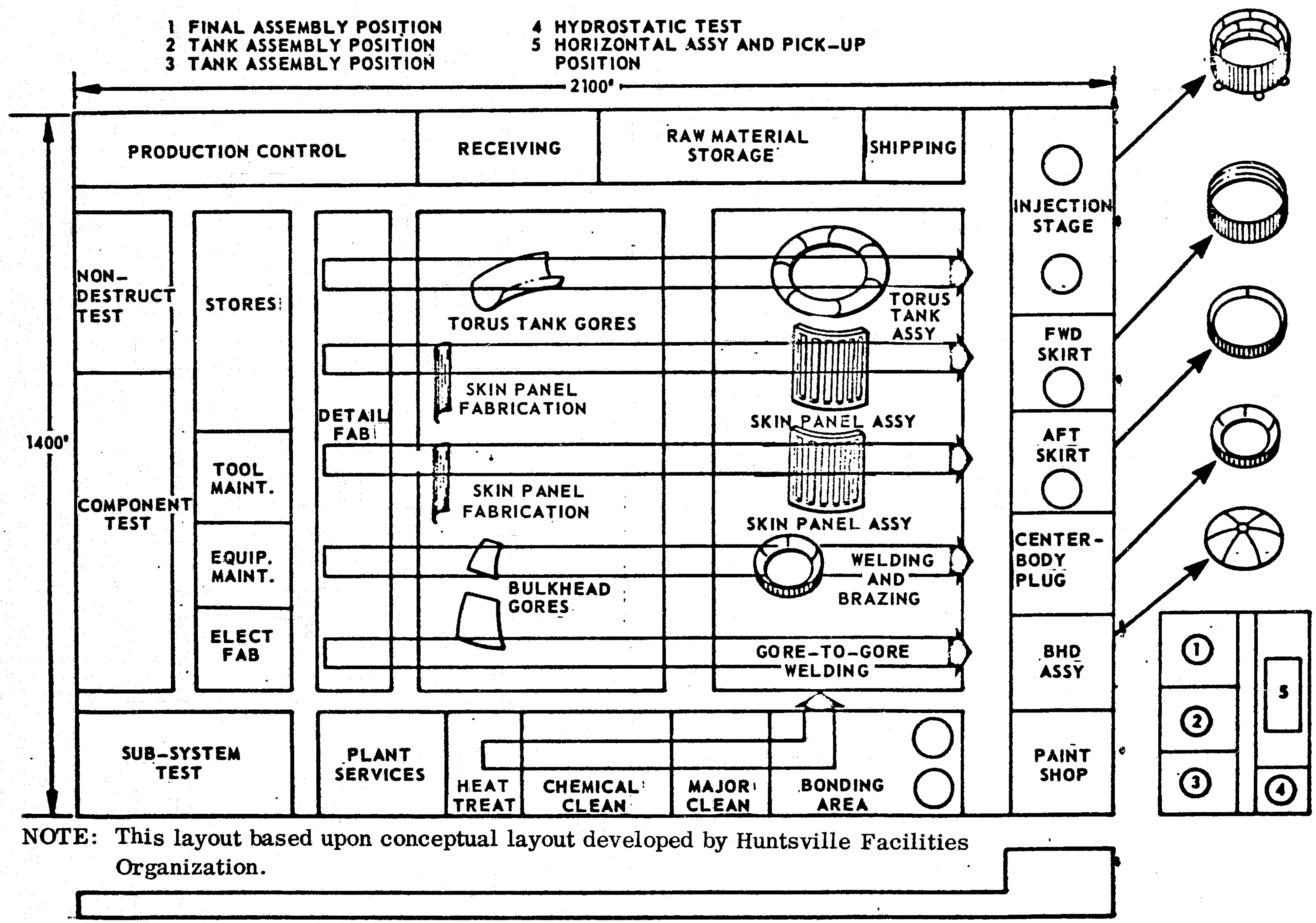


15. ATTACH CENTER BODY PLUG
TO TUBULAR TRUSSWORK



16. INSTALL ENGINES AND
ACCESSORIES

FIGURE 1.3.1.0-1 (SHEET 3 OF 3)



NOTE: This layout based upon conceptual layout developed by Huntsville Facilities Organization.

FIGURE 1.3.1.0-2 MAIN STAGE AND INJECTION STAGE MANUFACTURING FACILITY

TABLE 1.3.1.0-I Main Stage Manufacturing Resource Requirements Summary

Item	AMLLV			MLLV		
	Standard Forward Skirt	Alternate Forward Skirt	Multichamber/ Plug Engine Cluster	Standard Forward Skirt	Alternate Forward Skirt	Multichamber/ Plug Engine Cluster
"A" CATEGORY			*$111,200,000			*$ 78,300,000
Tool Manpower	14,320,976 M/H	15,230,456 M/H		9,407,795 M/H	9,980,768 M/H	
Tool Materials	$ 29,942,050	$ 31,533,640		$ 21,957,865	$ 21,957,865	
Facilities and Equipment	$162,150,000	$162,150,000		$148,777,000	$148,777,000	
"C" CATEGORY			**$ 71,100,000 1st Unit (24 Modules per Unit)			**$ 50,800,000 1st Unit (24 Modules per Cluster)
Manufacturing Manpower	2,309,082 M/H	2,473,365 M/H		1,992,865 M/H	2,096,163 M/H	
Vehicle Materials	$ 33,105,108	$ 33,342,622		$ 27,987,570	$ 28,128,391	
Facility and Equipment Maintenance	$ 8,141,000 Per Year	$ 8,141,000 Per Year		$ 7,776,000 Per Year	$ 7,776,000 Per Year	

* TOTAL "A" COSTS

** TOTAL "C" COSTS

1.3.1 (Continued)

a. "A" Category estimates for tool fabrication, erection and checkout manhours, tool materials and facilities.

b. "B" Category estimates for R&D test vehicle specimen costs (included in resource requirements for R&D test plan).

c. "C" Category estimates for stage materials, manufacturing manpower and facility maintenance.

The main stage engines were treated as purchased items. Either multichamber plug or toroidal/aerospike engines can be used on the main stage. The multichamber plug engine was selected for the baseline vehicle and estimates for "A" and "C" costs are summarized in Table 1.3.1.0-I. A subsequent paragraph will discuss the engines and other program options.

1.3.2 Injection Stage

There are three possible configurations of the injection stage. The smallest is an engine wafer with two engines; this stage is used with the main stage without any SRM strap-on stages. The next larger size is a engine wafer with four engines and a fuel module to supply additional propellants. The largest configuration has six engines installed on the lower module and two fuel modules for additional propellants. The manufacturing plan prepared for the injection stage applies to all possible combinations of modules. The plan shown is for the six engine version of the engine module. Four and two engine versions are manufactured with the same basic tools, with engines and other system items omitted as required in final assembly.

Fuel modules which supply additional tankage for the four and six engine modules are identical, except for omission of the thrust posts and heat shield. In addition to the above changes, the fuel tank pressurization system is installed in the engine module and the propellant manifolds are replaced by interconnect lines to the fuel module tanks. The manufacturing plan is summarized in Figures 1.3.2.0-1 and -2.

Flow through the manufacturing facility is shown in Figure 1.3.1.0-2, demonstrating that the main stage facility is shared. Resource requirements are summarized in Table 1.3.2.0-I.

The cost data for the injection stage engines was supplied by Pratt and Whitney Aircraft. The MLLV engine develops 125,000 pounds of thrust and the AMLLV engine 250,000 pounds. The "C" costs shown in Table 1.3.2.0-I are for the six engine version, thereby taking advantage of the learning curve effect on the production rate. Unit costs would increase with a production rate of less than 12 engines per year. Cost analysis was based upon two vehicles per year .

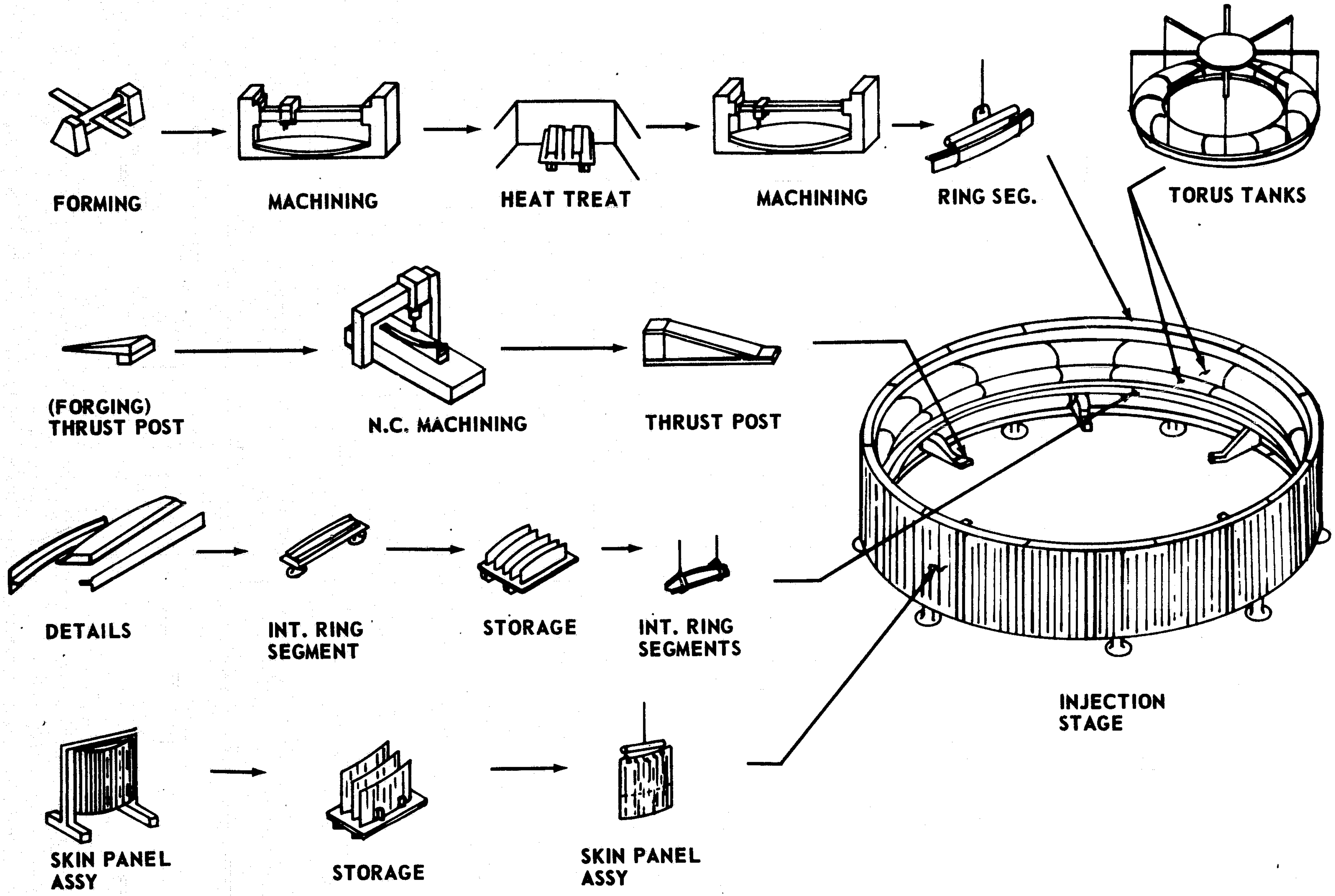


FIGURE 1.3.2.0-1 FINAL ASSEMBLY SEQUENCE

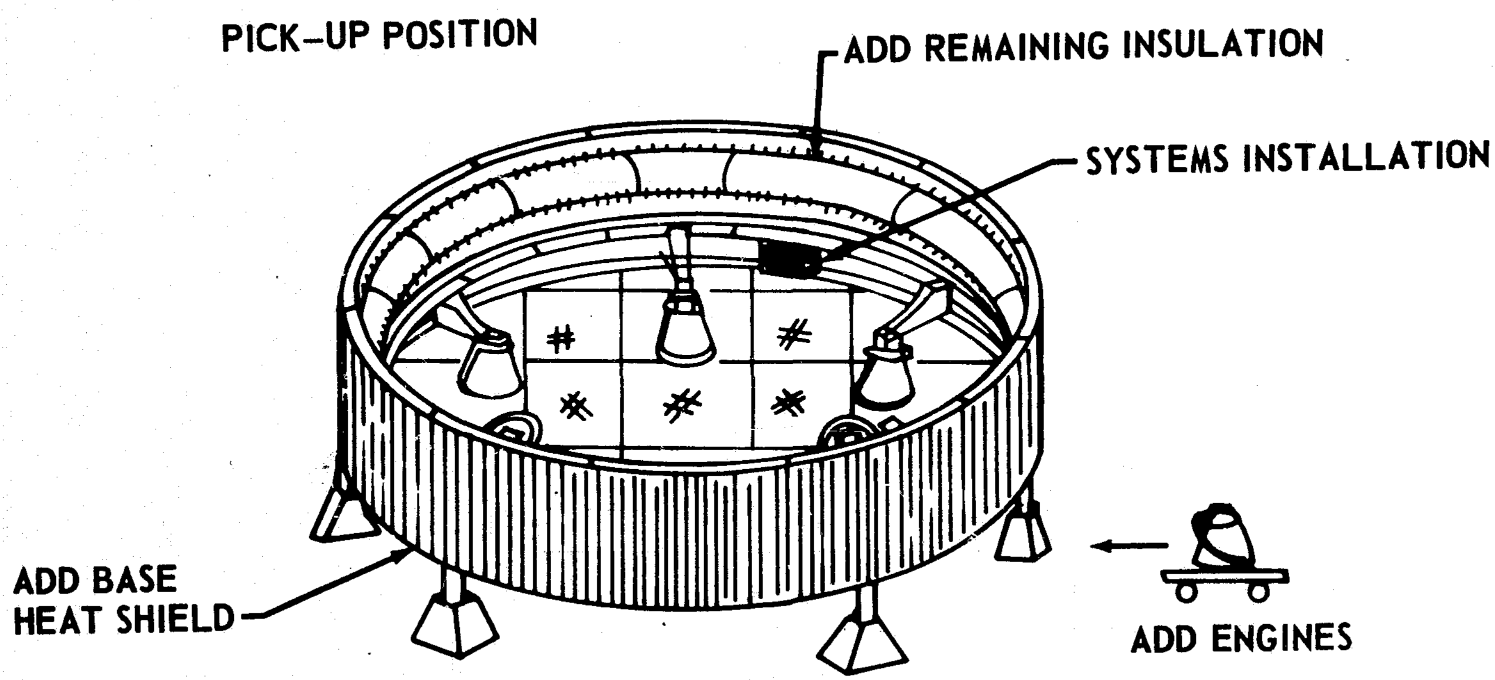


FIGURE 1.3.2.0-2 BASE HEAT SHIELD AND ENGINE INSTALLATION

TABLE 1.3.2.0-I Injection Stage Manufacturing Resource Requirements Summary

Item	Engine Module Designed for 2 Engines (1)	Engine Module Designed for 4 Engines (2)	Engine Module Designed for 6 Engines (3)	Fuel Module	Engines
<u>AMLLV</u>					
"A" CATEGORY					$ 60,200,000
Tool Manpower	3,141,774 M/H	These tools build all modules of the AMLLV injection stage.			
Tool Material	$ 6,045,786				AMLLV TOTALS
Facilities & Equipment	$54,050,000				
"C" CATEGORY					
Manufacturing Manpower	486,201 M/H	534,997 M/H	643,726 M/H	264,740 M/H	$ 10,850,000 1st Vehicle 6 Engines
Vehicle Materials	$ 2,046,549	$2,392,470	$2,738,286	$ 794,711	
<u>MLLV</u>					$ 41,500,000
"A" CATEGORY					
Tool Manpower	2,033,265 M/H	These tools build all modules of the MLLV injection stage.			
Tool Materials	$ 4,180,188				MLLV TOTALS
Facilities & Equipment	$ 49,593,000				
"C" CATEGORY					
Manufacturing Manpower	382,852 M/H	431,648 M/H	540,377 M/H	182,014 M/H	$ 7,590,000 1st Vehicle 6 Engines
Vehicle Materials	$ 1,519,192	$1,880,238	$2,140,911	511,602	

(1) For Single Module Injection Stage
(2) For Two Module Injection Stage
(3) For Three Module Injection Stage

1.3.3 Solid Rocket Motor Strap-On Stage

The sequential flow of the 260" SRM strap-on stage is shown in Figure 1.3.3.0-1. The structural assemblies consisting of the nose cone, forward skirt, aft skirt and attachment fittings will be fabricated at the main stage Mfg. facility and sent to the SRM contractors facility for assembly to the solid rocket motor. The remaining stage components and all facilities and equipment necessary for stage assembly, handling and transportation (accomplished by the SRM contractor) are included in the Aerojet General Corporation cost estimates. The manufacturing operations are summarized in Figure 1.3.3.0-2.

The estimates, prepared at Michoud for the structural assemblies, were prepared to the same level as those for the main and injection stage structure. In general, the Aerojet estimates are in the "A" and "C" categories but not to the same level of detail. The manufacturing resource requirements for the 260" SRM strap-on stage are summarized in Table 1.3.3.0-I.

1.4 TRANSPORTATION PLAN

Transportation of the main and injection stages resolves into two modes. Pneumatic tire units will be utilized within the confines of the manufacturing facility. Towed barges will be used to transport the stages to the launch facility. (Table 1.4.0.0-I.)

No land transportation of the SRM stage is required, as it is lifted directly from the casting pit and placed aboard the towed barge used to transport it to the launch facility.

At the launch facility all stages are lifted directly off their barges and placed in the selected location by a large traveling gantry hoist; therefore, no additional transportation equipment is required.

1.5 LAUNCH OPERATIONS PLAN

Launch of baseline study vehicles AMLLV or MLLV with SRM strap-on stages will require complete new facilities and operational procedures. A fixed, rather than a mobile system as used for the Saturn V, was selected. The launch pad will serve as the static firing stand for main and injection stages, the refurbishment facility, the vertical assembly and checkout facility and finally the launch pad.

The load lifting and transport concept is similar to the traveling gantry cranes used in shipyards. The gantry uses roll ramp actuators for hoisting its cross head to which the load is attached, and the traveling feature is accomplished by wheeled trucks on rails under each leg.

The general facility layout is shown in Figure 1.5.0.0-1.

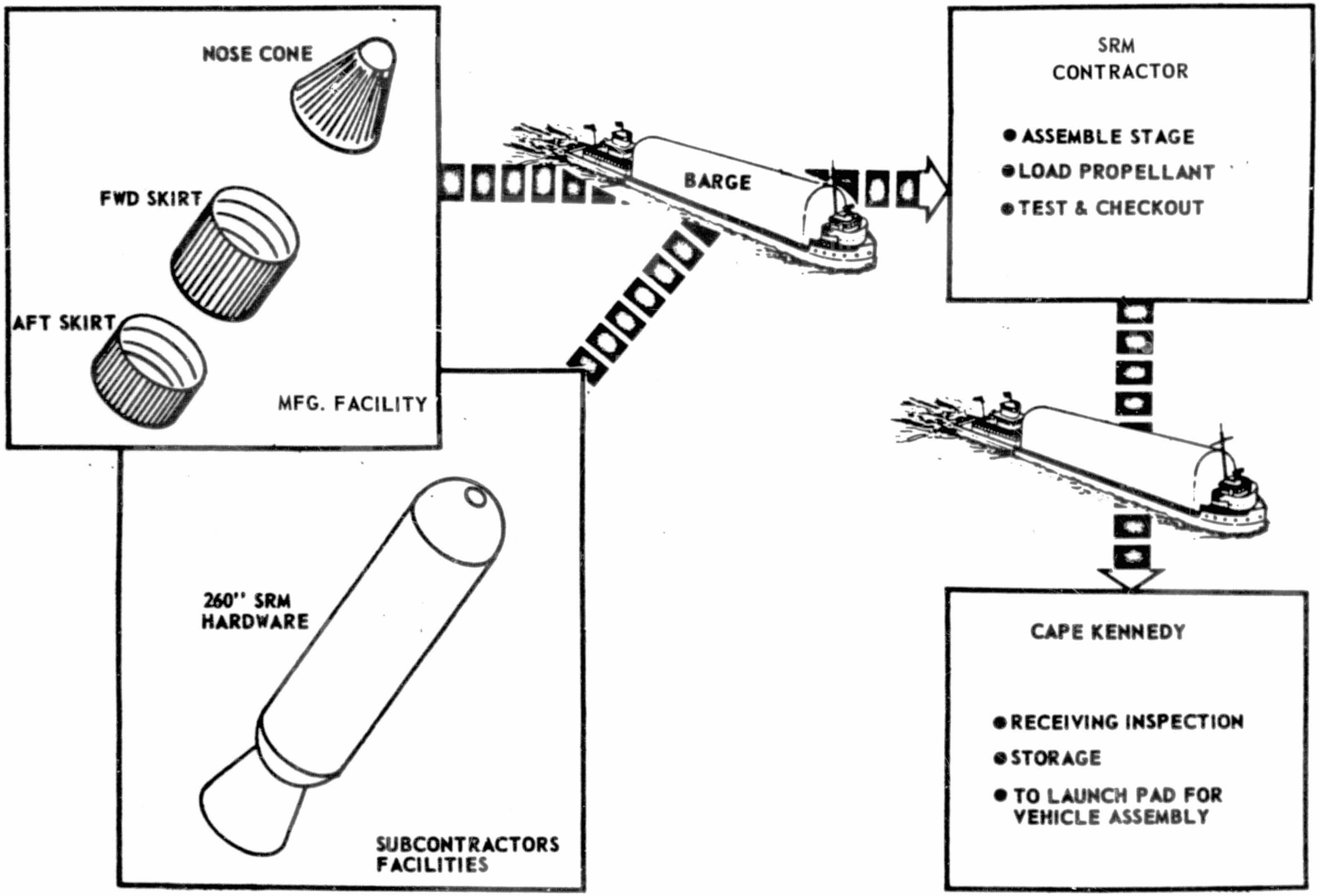


FIGURE 1.3.3.0-1 SRM STRAP-ON STAGE SEQUENTIAL FLOW

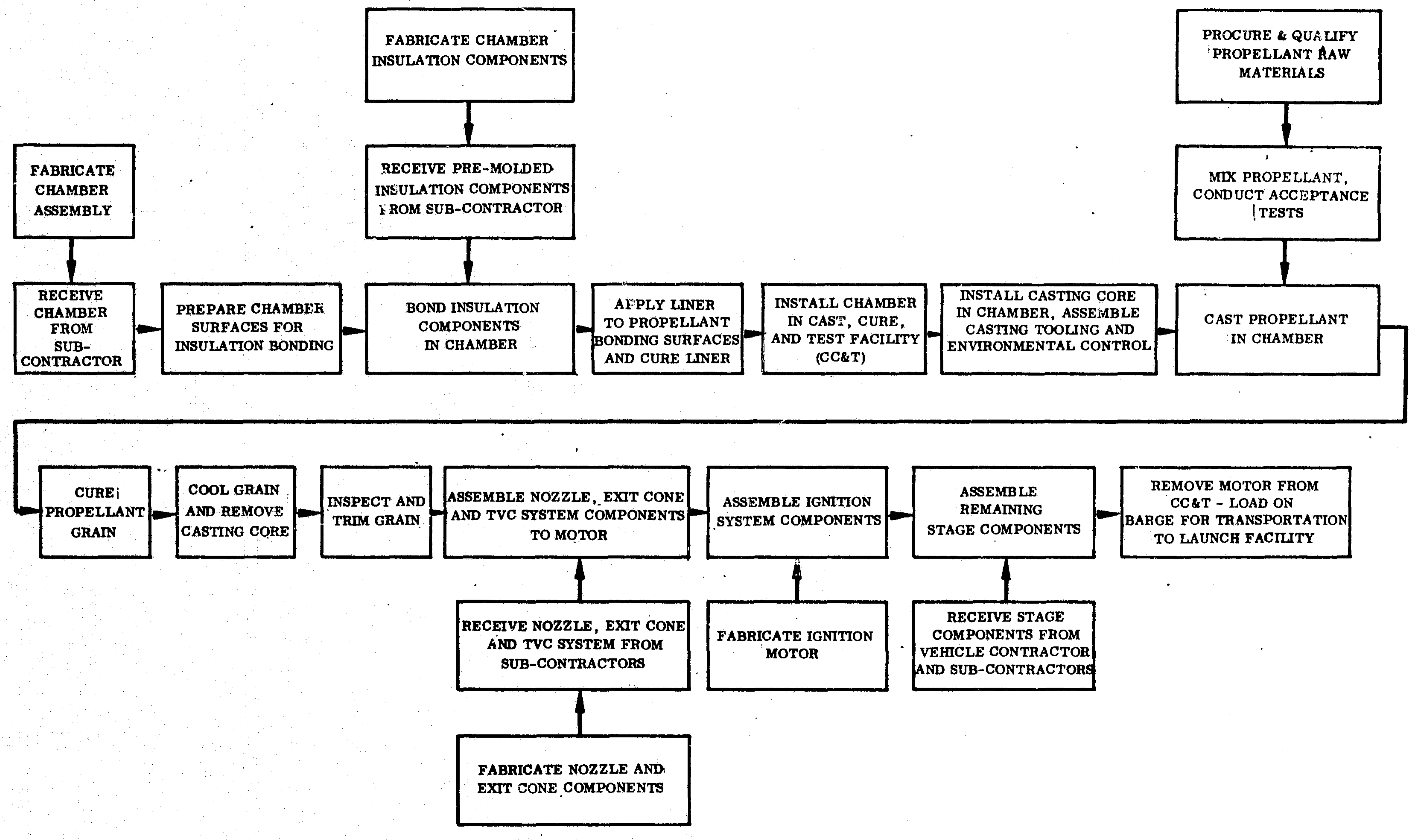


FIGURE 1.3.3.0-2 SRM STRAP-ON STAGE MANUFACTURING OPERATIONS

TABLE 1.3.3.0-I SRM Strap-On Stage Manufacturing Resource Requirements Summary

VEHICLE	AMLLV		MLLV	
LOCATION	MFG. FACILITY	SRM FACILITY	MFG. FACILITY	SRM FACILITY
"A" CATEGORY				
Tool Manpower	1,095,504 M/H	①	1,055,871 M/H	①
Tool Material	$1,917,132	$58,801,000	$1,847,744	$41,941,000
Facilities and Equipment	$5,624,000	$68,429,000	$5,504,000	$45,862,000
"C" CATEGORY ②				
Manufacturing Manpower	109,000 M/H	③	87,200 M/H	③
Vehicle Materials	$1,218,040	$ 7,725,000	$1,115,314	$6,102,000
Facility and Equipment Maintenance	$ 208,000 Per Year	③	$ 202,000 Per Year	③

① Included in Tool Material Estimate
② Estimates are for the First Stage ("C" Costs)
③ Included in recurring SRM Stage Estimate

TABLE 1.4.0.0-I TRANSPORTATION RESOURCE REQUIREMENTS SUMMARY

ITEM	AMLLV			MLLV		
	MAIN	INJECTION	SRM STRAP-ON	MAIN	INJECTION	SRM STRAP-ON
"A" CATEGORY						
Land Transporters	$2,394,000	$1,541,000	-0-	$2,155,000	$1,387,000	-0-
Tow Vehicle	$82,000	$82,000	-0-	$82,000	$82,000	-0-
Barges	$4,619,000	$2,592,000	$26,000,000	$4,157,000	$2,333,000	$18,000,000
"C" CATEGORY *			$176,000**			$176,000**
Land Transporter and Tow Vehicle Maintenance	$4,000	$3,000		$4,000	$3,000	
Barge Maintenance	$45,000	$20,000		$45,000	$20,000	
Barge Towing Service	$35,000	$16,000		$35,000	$16,000	

* Estimates are for each stage.

** Estimate supplied by Aerojet and includes all transportation requirements for each SRM strap-on stage.

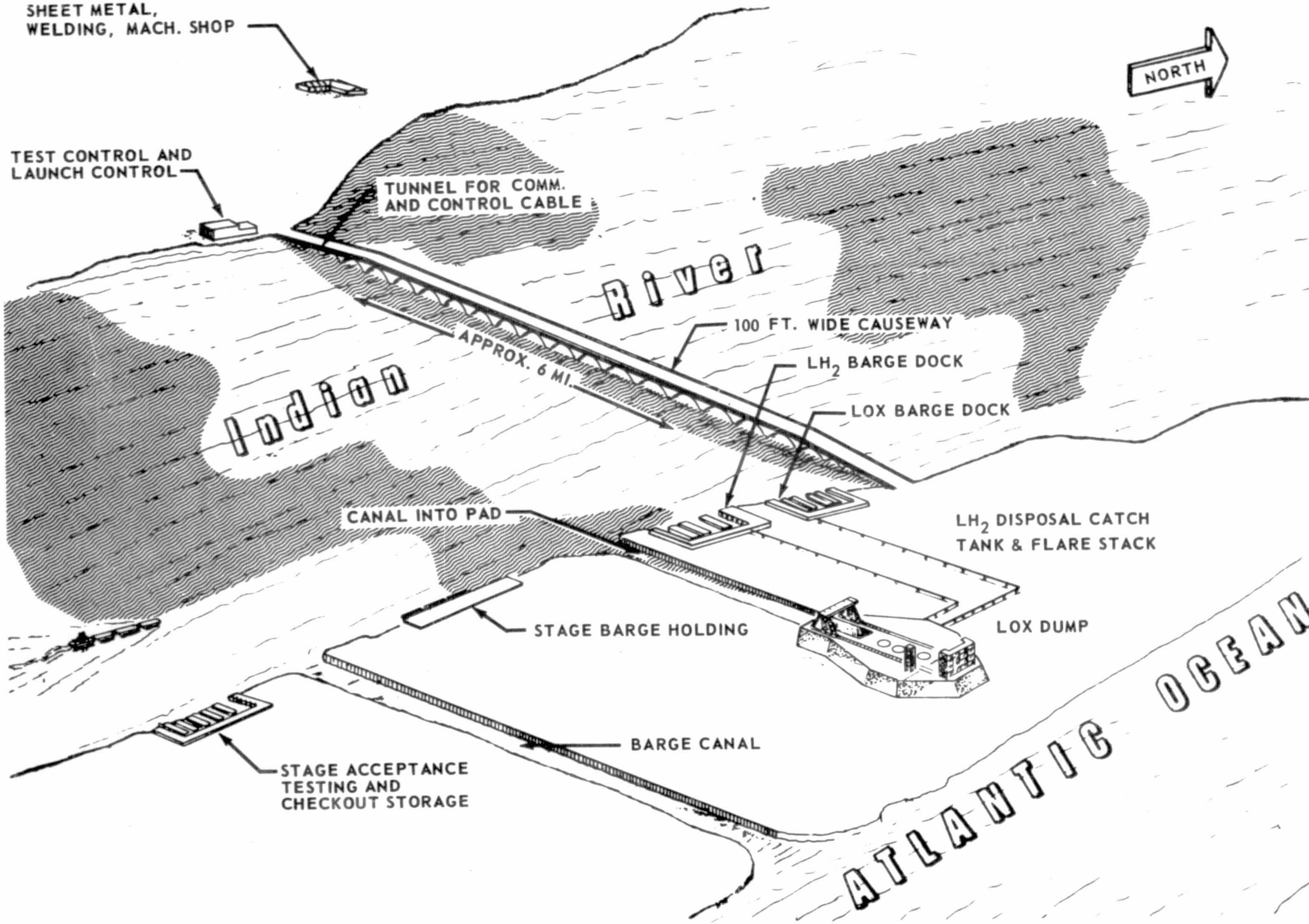


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FIGURE 1.5.0.0-1 AMLLV AND MLLV GENERAL FACILITY LAYOUT

1.5 (Continued)

Detailed sequential flow plans were prepared for all launch site operations. They were broken down to the level necessary to define the equipment, determine man loading and establish scheduling. Figure 1.5.0.0-2 summarizes the launch complex activities. The resource requirements are summarized in Table 1.5.0.0-I.

1.6 SCHEDULE PLAN

Timelines and/or schedules were developed for all the previously discussed plans (design through launch). These schedules are discussed in detail in Section 8.0, and are summarized in Figure 1.0.0.0-2, preceeding.

1.7 PROGRAM OPTIONS

The plans and resource requirements summarized in the preceeding paragraphs were based on a selected configuration concept. The main stage was equipped with a multichamber/plug engine system. Either multichamber/plug or toroidal/aerospike engines can be used on the stage.

NOTE: Engine Costs are based on data as provided by Rocketdyne for the toroidal/aerospike and by Pratt and Whitney for the multichamber/plug respectively. It is not certain whether the data as provided was developed on exactly the same basis. Therefore, any comparisons are of a general nature, and are not necessarily indicative of actual system differences.

a. The Pratt and Whitney cost data for the multichamber/plug engines (AMLLV and MLLV) is arranged in "A", "B" and "C" cost categories, but is not to the depth shown for the stage structures and systems. Table 1.7.0.0-I summarizes the program costs.

b. The toroidal/aerospike engine cost data has been prepared for several concepts. Two concepts are for the MLLV, both having 1200 PSIA chamber pressure, one of which is based on using J-2S turbo-machinery, and the other uses new turbo-machinery.

   Three concepts are for 2000 PSIA chamber pressure engines using new turbo-machinery. Two concepts are for the AMLLV, the first of which has a million pound thrust module and the second a two million pound thrust module. The third concept is for the MLLV, and has a million pound thrust module.

   The cost data for the AMLLV is summarized in Table 1.7.0.0-II and the MLLV data in Table 1.7.0.0-III.

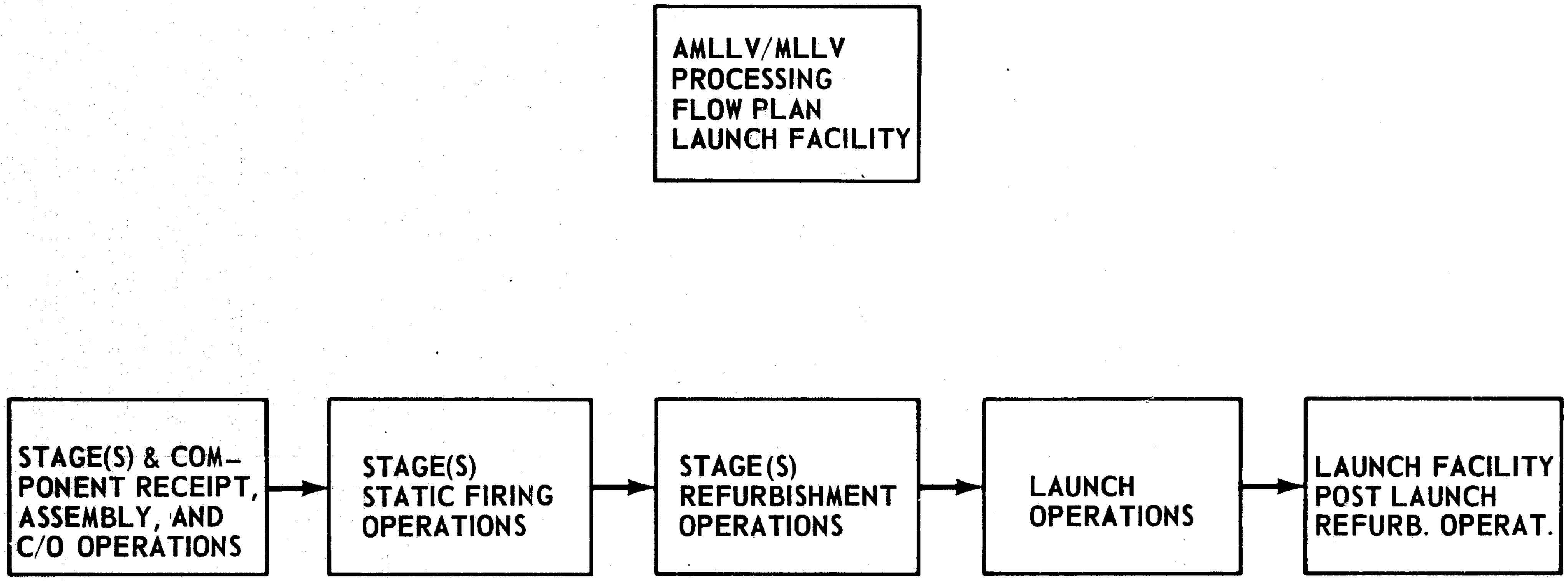

FIGURE 1.5.0.0-2 MASTER CHART, LAUNCH COMPLEX ACTIVITIES

TABLE 1.5.0.0-I LAUNCH RESOURCE REQUIREMENTS SUMMARY

ITEM	AMLLV		MLLV	
	SINGLE - STAGE - TO - ORBIT (1)	MAXIMUM VEHICLE (2)	SINGLE - STAGE - TO - ORBIT (1)	MAXIMUM VEHICLE (2)
"A" CATEGORY				
Brick & Mortar	$137,900,000	$539,709,000	$ 54,400,000	$496,783,000
Equipment	$ 70,000,000	$149,334,000	$ 68,000,000	$149,334,000
Totals	$207,900,000	$689,043,000	$122,400,000	$646,117,000
"C" CATEGORY				
Engineering	1,249,000 M/H	1,540,000 M/H	1,195,000 M/H	1,450,000 M/H
Non-Engineering	19,191,000 M/H	23,573,000 M/H	18,296,000 M/H	22,191,000 M/H
Facility Maintenance	$ 8,750,000	$ 9,900,000	$ 8,750,000	$ 9,900,000
Expendibles	$ 4,905,000	$ 6,540,000	$ 2,452,875	$ 3,270,500

NOTES:

(1) The single-stage-to-orbit configuration is launched from launch complex 39 modified as required for the AMLLV and MLLV vehicles.

(2) The maximum vehicle is a main stage, 3 module injection stage and the maximum number of SRM strap-on stages (8 for the MLLV and 12 for the AMLLV) which requires the construction of a new complex.

TABLE 1.7.0.0-I Multichamber/Plug Engine Cost Summary

CATEGORY	COST ITEM	AMLLV	MLLV
	Engineering	$ 37.5M	$ 26.4M
	Equipment	1.3M	1.0M
	Tooling (Basic)	13.2M	9.2M
"A" COSTS	Subtotal	$ 52.0M	$ 36.6M
	Production		
	Tooling (Basic)	$ 32.9M	$ 23.1M
	Equipment	9.8M	7.0M
	GSE	16.5M	11.6M
	Subtotal	$ 59.2M	$ 41.7M
	Total	$111.2M	$ 78.3M
	Engineering	$143.2M	$100.8M
	Test	54.0M	38.0M
	Equipment	15.2M	10.8M
"B" COSTS	Tooling (Basic)	11.5M	8.1M
	Fabrication	154.9M	109.0M
	Subtotal	$378.8M	$266.7M
	Oxygen Fuel	$ 30.2M	$ 15.5M
	Hydrogen Fuel	83.9M	43.2M
	Subtotal	$114.1M	$ 58.8M
TOTAL NON-RECURRING		$604.1M	$403.8M
	Engineering	$ 3.4M	$ 2.4M
	Test	4.6M	3.3M
"C" COSTS	Tooling (Maint.)	5.2M	3.7M
	Fabrication	57.9M	41.4M
1ST VEHICLE RECURRING		$ 71.1M	$ 50.8M

TABLE 1.7.0.0-II AMLLV - Toroidal/Aerospike Engine Cost Summary

CHAMBER PRESSURE		2000 PSI	2000 PSI
MODULE THRUST (LBS)		1000 K	2000 K
CATEGORY	COST ITEM	DOLLARS IN MILLIONS	
	Design and Development		
"A"	Engineering	$ 43.2	$ 50.5
	Test	11.2	13.0
+	Equipment	16.4	21.1
"B"	Tooling (Basic)	7.0	10.0
	Fabrication	55.0	89.9
	Subtotal	$132.8	$184.5
	Production		
	Tooling (Basic)	$ 4.0	$ 6.0
	Equipment	3.0	3.5
	GSE	4.5	6.0
	Subtotal	$ 11.5	$ 15.5
Total Non-Recurring		$144.3*	$200.0*
	Production		
		First Unit	First Unit
	Engineering	$ .15	$ .25
	Test	.18	.30
	Tooling (Maintenance)	.26	.42
	Fabrication	2.51	4.09
"C"	Total Per Module	$ 3.10	$ 5.06
		60th Unit	30th Unit
	Engineering	$ .09	$ .17
	Test	.11	.21
	Tooling (Maintenance)	.17	.30
	Fabrication	1.55	2.75
	Total Per Module	$ 1.92	$ 3.43

* Propellants for the R&D Test Program were assumed to be Government furnished

TABLE 1.7.0.0-III MLLV - Toroidal/Aerospike Engine Cost Summary

CHAMBER PRESSURE		1200 PSI		2000 PSI
MODULE THRUST (LBS)		286K*	1000K	1000K
CATEGORY	COST ITEM	DOLLARS IN MILLIONS		
	Engineering	$ 5.7	$ 7.5	
	Equipment	.2	.5	Included in "B"
	Tooling (Basic)	2.0	3.0	
"A"	Subtotal	$ 7.9	$ 11.0	
	PRODUCTION			
	Tooling (Basic)	$ 5.0	$ 4.0	$ 4.0
	Equipment	1.5	2.5	3.0
	GSE	2.5	4.0	4.5
	Subtotal	$ 9.0	$ 10.5	$ 11.5
	Total	$16.9	$ 21.5	$ 11.5
	Engineering	$24.5	$ 37.8	$ 43.2
	Test	7.1	10.1	11.2
"B"	Equipment	2.2	16.1	16.4
	Tooling (Basic)	3.5	6.0	7.0
	Fabrication	20.3	51.9	58.0
	Subtotal	$57.6	$121.9	$135.8
Total Non-Recurring		$74.5	$143.4	$147.3
	PRODUCTION	First Unit	First Unit	First Unit
	Engineering	$ .06	$ .14	$ .15
	Test	.08	.17	.18
	Tooling (Maintenance)	.09	.24	.27
	Fabrication	1.01	2.36	2.64
"C"	Total Per Module	$ 1.24	$ 2.91	$ 3.24
		100th Unit	30th Unit	30th Unit
	Engineering	$ .04	$ .09	$ .10
	Test	.05	.11	.12
	Tooling (Maintenance)	.61	1.59	1.78
	Total Per Module	$ .75	$ 1.95	$ 2.18

* Uses J-2S Turbo-Machinery

2.0 GUIDELINES AND ASSUMPTIONS

The guidelines and assumptions for this study were developed from the contractual requirements, the previous AMLLV study (NAS2-4079), and applicable data from previous and current studies. Where special circumstances dictated an arbitrary assumption, The Boeing Company and the NASA technical monitor concurred on a suitable guideline.

a. General

1. The resource plans were based on current Saturn V philosophies to the maximum extent possible. No attempt was made to tailor the program for cost optimization.

2. A facility checkout vehicle will be provided that can be used to check out the facilities, GSE and tooling required for fabrication, test and launch.

3. Cost estimates were based on 1968 dollars without application of inflationary factors.

4. Where possible, the cost estimates were based on direct costs with burden costs added as a separate item.

b. Engineering Design

Office space at the Michoud Complex will be considered adequate to house the engineering staff for the research and design effort required for either the AMLLV or MLLV programs. Also, adequate engineering laboratories with support facilities presently exist, so that no new facilities will be needed to support engineering design.

c. Testing

1. The vehicles will be manrated. The necessary combination of ground and flight testing was established to achieve this result.

2. The development test program for either the AMLLV or the MLLV will each provide for two unmanned flight tests of the maximum size configuration in the selected vehicle family.

3. Engine module acceptance test firing and trim by engine contract will be required.

4. Present NASA/MSFC and KSC philosophies will be continued.

5. A dynamic test will be included in each program (either AMLLV or MLLV) for the maximum size vehicle (strap-ons will be simulated).

2.0 (Continued)

6. Development testing of the main stage and injection stage will be conducted in new dynamic and structural test facilities constructed adjacent to the factory building.

7. Static test firing will be required for final acceptance of the main stage and injection stage.

8. Static test firing will be conducted on the launch pad.

9. Maximum utilization will be made of existing government and industry ground test facilities and test equipment.

10. Early development testing will be limited to testing in existing facilities.

d. Manufacturing

1. The production rate will be limited to 2 flight vehicles per year.

2. All stages will be built adjacent to a navigable body of water.

3. Main stages and injection stages will be fabricated at the NASA Michoud site (or its equivalent located on a navigable waterway) in a new factory building.

4. SRM stages will be assembled at the Aerojet General Facility in Dade County, Florida.

e. Transportation and Handling

1. Assembled stages will be transported from the manufacturing facility to the launch facility by water.

2. Main stages will be transported in a horizontal attitude.

3. SRM stages will be transported in a horizontal attitude.

4. Payload will be transported by water in either a horizontal or vertical attitude, depending on size and clearance problems.

f. Launch

1. Operational launches will be evenly spaced with one launch every six months.

2. The launch site will be in the vicinity of Cape Kennedy to utilize the available facilities, support equipment, personnel, and existing tracking networks.

2.0 (Continued)

3. Although the acoustic siting criteria indicate that an off-shore site is required, an on-shore site will be used to provide credibility to facility, equipment, tooling and cost requirements.

4. Mating of SRM and injection stages to the main stage will be at launch site.

5. Siting of launch pads will be based upon 20 percent (TNT equivalency) yield of solids when mounted on fueled core, with 60 percent (TNT equivalency) yield of LH_2/LOX.

6. The vehicle, supported in the launch stand at its holddown points, must be capable of withstanding a hurricane, but not necessarily without braces or tie downs (i.e., not self-supporting under hurricane conditions.)

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3.0 DESIGN PLAN

This design plan was developed to define the engineering requirements for initial design, R&D support and sustaining engineering during production and launch. The plan was based on past experience with similar plans and estimates, and on historical data from the S-IC and Saturn V programs. This plan is applicable to both the AMLLV and MLLV vehicle families.

The design plan was prepared assuming that the design of the main stage, injection stage and solid rocket motor (SRM) stages will proceed in parallel.

Using the conceptual designs of the AMLLV and MLLV vehicle families and S-IC historical engineering design records, schedules, a design plan and manpower estimates were prepared. The manpower estimates were then used to develop engineering design costs.

Paragraph 3.1 presents a description of program phases and the engineering schedule. Paragraph 3.2 reviews design resource requirements for manpower, equipment and facilities.

This Design Plan is for the launch vehicle only and does not include tool, GSE and facility design requirements. These requirements are shown as they are applicable, in the subsequent Test, Manufacturing, Transportation and Launch plans.

Engineering design resource requirements applicable to the R&D program are not shown in this Design Plan resource requirements, but are shown in the resource requirements for the Development and Test plan.

3.1 DESIGN PLAN DESCRIPTION

The engineering design sequential plans for the full size (AMLLV) and the half size (MLLV) vehicles were based on compliance with the NASA Policy Directive, NPD 7121.1, Phased Project Planning, dated October 28, 1965. This policy directive defines the four project phases. Figure 3.1.0.0-1 defines these phases and their outputs in a summary form.

This Design Plan was prepared for Phases C and D. The time span of the Design Plan, exclusive of sustaining engineering, will be 8-1/2 years, starting 6 months after the end of Phase B and ending with completion of the R&D program.

The Phase C design activity will refine the preliminary design and specifications prepared in the earlier Phase B activity. The Phase C design activity will provide working drawings to manufacture test articles, monitor the R&D tests, and will provide the final design. Results from the R&D test program will indicate the changes that must be made in the design; therefore, the design activity cannot be considered to be complete until after completion of all R&D testing. Phase C will be completed upon release of final drawings and specifications for Phase D procurement, or production articles for the operational program.

PHASE A PRELIMINARY ANALYSIS	PHASE B DEFINITION	PHASE C DESIGN	PHASE D DEV. / OPERATIONS
• DEVELOP PROJECT OBJECTIVES • ASSESS FEASIBILITY • IDENTIFY RESEARCH AND ADVANCED TECHNOLOGY REQUIREMENTS • DEVELOP GROSS PLANS FOR IMPLEMENTATION • PERFORM TRADE-OFF ANALYSIS • IDENTIFY FAVORABLE & UNFAVORABLE FACTORS • DEFINE RELATIONSHIPS TO PROGRAMS	• REFINE SELECTED ALTERNATIVE CONCEPTS • CONDUCT SYSTEMS ANALYSIS • DEVELOP PRELIMINARY DESIGN AND SPECIFICATIONS • ASSESS PRELIMINARY MANUFACTURING AND TEST REQUIREMENTS • IDENTIFY ADVANCED TECHNOLOGY AND ADVANCE DEVELOPMENT REQUIREMENTS • ASSESS COSTS AND SCHEDULES • DEFINE MANAGEMENT AND PROCUREMENT APPROACHES • TRADE-OFF ANALYSIS	• DEVELOP DETAIL OF SELECTED CONCEPT • DEVELOP SPECIFIC DESIGN AND SPECIFICATIONS • DEVELOP PLANS FOR MANUFACTURING, TESTING, SUPPORTING SYSTEMS, FACILITIES, ETC. • INITIATE REQUIRED LONG-LEAD ADVANCE DEVELOPMENT AND DEFINE PLAN FOR SUPPORTING DEVELOPMENT • DEVELOP SCHEDULES AND ESTIMATES OF COSTS • REFINE MANAGEMENT AND PROCUREMENT PLAN	• DEVELOP & TEST • MANUFACTURE • CHECKOUT • OPERATE
• FEASIBLE PROJECT CONCEPTS FOR DETAILED STUDY	• SPECIFIC PROJECT CONCEPT FOR DETAILED DESIGN • PRELIMINARY SPECIFICATIONS • PRELIMINARY SCHEDULE, RESOURCE & MANAGEMENT PLANS	• PROJECT DESIGN & SPECIFICATIONS INCLUDING MANUFACTURE, TEST & OPERATION PLANS • SCHEDULE, RESOURCES, MANAGEMENT & PROCUREMENT PLANS	• COMPLETED PROJECT

FIGURE 3.1.0.0-1 PHASED PROJECT PLANNING PHASE RELATIONSHIP

3.1 (Continued)

The initial Phase D activity will: 1) provide the facilities, tooling and equipment; 2) manufacture the test articles and 3) conduct the R&D tests. The Phase D production program will phase into the latter portion of the R&D program. Phases C and D, by definition, must overlap.

The engineering design functions consist of:

a. Initial design, monitoring of the R&D program and final design (non-recurring activity);

b. Sustaining engineering during the production program (recurring activity).

Initial design will be the analysis and drawing activity required to describe the basic concept. At the end of this activity, the design is considered to be 90 percent complete. All drawings will have been released. Many changes, however, will be made as a result of R&D test results and also to incorporate desirable improvements. Engineering design support of the R&D program will consist of determining test requirements, monitoring the test activities, analyzing the results, and revising the design.

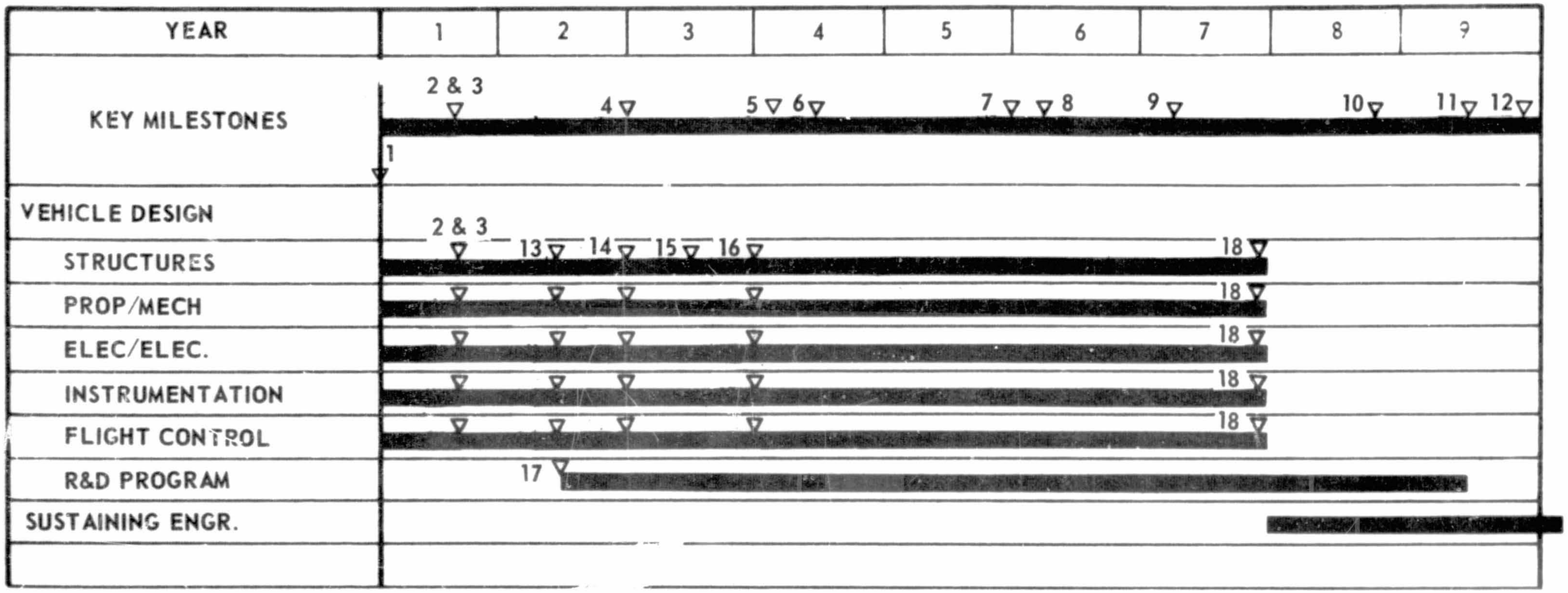
The sustaining design engineering activity will consist of incorporating those changes required in the design to allow for improvements, variation in number and type of measurements and changes required for different types of missions.

Figure 3.1.0.0-2 shows the engineering schedule. This schedule is applicable to both the AMLLV and MLLV programs. The release dates are programmed to match the manufacturing requirements for data.

3.2 RESOURCE IMPLICATIONS

Discussion of resource requirements for engineering design activity is limited to manpower requirements. Adequate facilities and equipment are considered to be available at the Michoud site where the manufacturing operations could be based.

Engineering design manpower does not appear to be proportional to vehicle size or weight, as shown by comparison of the engineering design manhours required for the half size (MLLV) vehicle configuration with those required for the full size (AMLLV) vehicle configuration. Complexity and quantity of vehicle systems appears to be the parameter that determines the required design effort. Estimates of stage complexity can be made by comparing system operational life, number of systems, effects of a system failure and number of functions performed by the system and by determining whether its design is, or is not, within the present state-of-the-art.



▽ 1 TOP DRAWING AND SPECIFICATION RELEASE COMPLETE	▽ 8 "DTV" VEH. AVAILABLE	▽ 15 STRENGTH CHECKS COMPLETE
▽ 2 TEST REQUIREMENTS DEFINED	▽ 9 R&D TESTS (EXCEPT FLIGHT)	▽ 16 INITIAL DRAWING RELEASE COMPLETE
▽ 3 AUTHORIZATION TO PROCEED WITH PHASE D	▽ 10 1ST R&D LAUNCH	▽ 17 PLAN AND MONITOR R&D TESTS
▽ 4 START DETAIL PARTS FAB.	▽ 11 2ND R&D LAUNCH	▽ 18 MODIFICATIONS OF R&D VEHICLE COMPLETE
▽ 5 TEST PLANS FINALIZED	▽ 12 DRAWINGS FINALIZED WITH RESULTS FROM R&D PROGRAM	
▽ 6 START "F" VEH. ASSY.	▽ 13 RELEASE OF COMPONENT DRAWINGS INITIATED	
▽ 7 "F" VEH. THRU POST/MFG. T&CO.	▽ 14 SYSTEM PERFORMANCE ANALYSIS COMPLETE	

FIGURE 3.1.0.0-2 DESIGN SCHEDULE

3.2.1 Manhours for Design Activity (Inputs for Category "A" Get Ready Costs)

Using the S-IC stage design manhours as a basis, estimates were prepared for the main stages and injection stages of the two study vehicles. Table 3.2.1.0-I is a summary of the engineering manhours for the design task. The following notes (referenced in Table 3.2.1.0-I) explain how the manhours were estimated.

1. S-IC records did not record the design manhours for the individual structural systems. It is believed system complexity is reflected in the required manufacturing manhours. Design manhours attributed to the individual S-IC structural elements were therefore determined by a ratio of the manufacturing manhours required for the individual structural element to the total manufacturing manhours required for the S-IC stage for Saturn V vehicle No. 10.

2. The standard (lightweight) forward skirt for the MLLV will be similar to that of the S-IC, therefore, a small allowance was made for the effect of size and for the addition of the holddown fittings.

3. An allowance was made for the effect of maximum obtainable sheet stock. More joints will be required for the AMLLV forward skirt than for the MLLV forward skirt.

4. The injection stage skirt will also serve as the thrust structure (item 7 below) when thrust posts are added. A total of 150,000 manhours was estimated for design of the load carrying structure,which will be more complex than the S-IC forward skirt and less complex than the S-IC thrust structure.

5. The injection stage fuel module will be similar to the injection stage engine module, but will not contain the propulsion and mechanical, electrical/electronic, instrumentation and flight control subsystems. The purpose of the fuel module will be to provide additional propellant tankage. Provisions in the form of propellant tunnels between the fuel and engine module will be designed. (The engines will always be attached to the engine module so that the module must be designed for the maximum (six engine) propulsion system.) 45,000 design manhours will be required to adapt the engine module component designs into the fuel module design.

6. The main stage thrust structure design task should be less difficult than that for the S-IC. Much of the engineering effort on the S-IC stage was involved with the heat shield. In this case, the center plug will take the place of a heat shield; therefore, the design hours were reduced by approximately 25 percent. 5,000 manhours were added for the AMLLV over that required for the MLLV thrust structure to account for material size effects.

TABLE 3.2.1.0-I INITIAL DESIGN ENGINEERING MANHOUR SUMMARY

SYSTEM	S-IC	MAIN STAGE MLLV	MAIN STAGE AMLLV	INJECTION STAGE ENGINE MODULE MLLV	INJECTION STAGE ENGINE MODULE AMLLV	INJECTION STAGE FUEL MODULE MLLV	INJECTION STAGE FUEL MODULE AMLLV
STRUCTURE	765	1200	1245	570	570	45 ▽5	45
FWD SKIRT	(99)	(105) ▽2	(120) ▽3	(75) ▽4	(75)	(30) ▽5	(30)
THRUST STRUCTURE	(300)	(225) ▽6	(230) ▽6	(75) ▽7	(75)	N/A	N/A
LH_2 TANK	(99)	(105) ▽8	(105)	(150) ▽9	(150)	—	—
▽1 LOX TANK	(114)	(225) ▽10	(235)	(150) ▽9	(150)	—	—
BASE PLUG	—	(375) ▽11	(390)	—	—	—	—
TUNNELS & DUCTS	(84)	(90) ▽12	(90)	(60) ▽13	(60)	(15) ▽5	(15)
ASSEMBLY	(69)	(75) ▽12	(75)	(60) ▽13	(60)	—	—
PROPULSION & MECHANICAL	375	375 ▽14	375	300 ▽14	300	N/A	N/A
ELECTRICAL	187	225 ▽15	255	180	180	N/A	N/A
INSTRUMENTATION	435	600 ▽16	600	450	450	N/A	N/A
FLIGHT CONTROL	57	120 ▽17	120	120	120	N/A	N/A
ASSEMBLY & MISC.	540	600 ▽18	600	450	450	—	—
ALTERNATE FWD SKIRT		225 ▽19	(225)	—	—	—	—
CORE VEH (NO SRM STAGES)	2,359	3,120	3,165	2,070	2,070	45 ▽5	45
CORE VEH (PROVISIONS FOR SRM'S)		3,345	3,390	2,070	2,070	45	45

NOTE : ▽ COMMENTS IN TEXT BODY

MANHOURS IN THOUSANDS

3.2.1 (Continued)

7. The thrust structure for the injection stage will consist of six thrust posts and two ring frames. Approximately one-fourth of the design task on the S-IC thrust structure was involved with the design of the thrust posts; therefore, 75,000 manhours were estimated for the design of the injection stage thrust structure.

8. The design task for the hydrogen tank will be similar to the task of designing the RP-1 tank for the S-IC, except for the cryogenic temperatures and only one bulkhead. The common bulkhead between the fuel and oxidizer tank was considered to be part of the LOX tank.

9. The torus propellant tanks for the injection stage fuel module will be identical to the injection stage engine module fuel tanks. It is anticipated that considerable effort will be required in engineering as well as manufacturing development for design of these tanks.

j. The LOX tank will include the common bulkhead. It was estimated that the design task will be about double that of the design of the S-IC LOX tank.

11. The base plug will be a regeneratively cooled, composite structure of monel and aluminum honeycomb. Because of the environments to be experienced by this structure, it is anticipated that the design and analysis tasks will be of major proportions, probably greater than the thrust structure design task.

12. The main stage tunnel and duct design tasks and the structure assembly design tasks should be equivalent to similar tasks on the S-IC.

13. The injection stage will use a manifold-sump system for feeding propellants to the engines. 60,000 manhours each were estimated for the design tasks for tunnels and ducts and for injection stage structure assembly.

14. The propulsion and mechanical systems for the study vehicles will be similar to those on the S-IC; therefore, it was assumed that the design tasks will be of the same magnitude.

15. Incorporation of the automatic test and checkout system will increase the complexity of the electrical system over that of the S-IC.

16. The increased functions to be performed by the automatic test and checkout system will require more design manhours for the increased vehicle instrumentation.

3.2.1 (Continued)

17. The stage flight time will be increased, thereby requiring a longer life-span of the flight control system. It is estimated that double the S-IC design manhours would be required.

18. System assembly design and interface control design tasks should be similar to those on the S-IC.

19. The alternate forward skirt must be capable of reacting the loads of the SRM strap-on stages. The strap-ons will produce complicated load paths, dependent on the number used, and will require considerably more engineering design and analyses than the standard forward skirt.

The SRM subcontractor will design, develop and manufacture the solid rocket motors. The prime contractor will be responsible for the overall stage design and will design, develop and manufacture the SRM attach structures, the nose cone, and the forward and aft skirts. SRM stage assembly and post-assembly tests will be the responsibility of the SRM subcontractor.

Table 3.2.1.0-II shows the manpower requirements for the initial design of the strap-on stages. Estimates for the SRM's were provided by Aerojet General Corporation in terms of dollars, which were then converted to manhours. Design hours for the attachment structures and nose cone were obtained from the results of a prior study, e.g., "Saturn V Vehicle with 260-Inch Diameter Solid Motor Study," NASA Contract NAS8-21105. These prior inputs were developed by the Boeing-Michoud Manufacturing Organization.

Table 3.2.1.0-II: INITIAL DESIGN ENGINEERING MANPOWER SUMMARY FOR STRAP-ON STAGES, AMLLV AND MLLV

	MANHOURS	
	MLLV	AMLLV
SOLID ROCKET MOTOR (INCLUDING TVC)	152,000	160,711
NOSE CONE	13,340	13,340
FORWARD ATTACHMENT SKIRT	30,740	30,740
AFT ATTACHMENT SKIRT	8,700	8,700
FITTINGS	5,220	5,220
TOTALS	210,000	218,711

3.2.2 Manhours for Design Support of R&D Program (Inputs for "B" Costs)

The engineering support of the R&D program was broken down into three categories:

a. Manpower to plan and monitor the R&D tests. This manpower could not be specifically separated from the design activity and is shown in Section 3.2.1 above ;

b. Sustaining engineering manpower to support production of test articles. This manpower is allocated to specific test specimens in the subsequent Development and Test Plan, Section 4.0.

c. Engineering manpower to conduct R&D tests. This manpower is allocated to specific tests in the subsequent Development and Test Plan.

3.2.3 Manhours for Sustaining Engineering (Inputs for "C" Costs)

Sustaining engineering manhours for the main stage, injection stage, and strap-on stage attachment structure and nose cone were estimated using the same ratio of sustaining engineering to the initial design engineering as that experienced on the S-IC program. This sustaining engineering was further broken down as follows:

Design and Development	85.1%
Reliability	1.8%
Logistics	13.1%
Total Sustaining Engineering	100.0%

Sustaining engineering hours for the SRM and other strap-on stage components were provided as a direct input in terms of dollars from Aerojet General Corporation. These dollar estimates were factored into manhour estimates using average labor rates. No significant difference in the sustaining engineering effort between the MLLV and AMLLV could be determined; therefore, the following manhours summaries are generally applicable to both vehicle programs except as noted.

Tables 3.2.3.0-I through 3.2.3.0-III show the sustaining manhour summary for the main stage, the three module injection stages and the SRM strap-on stages respectively. The sustaining engineering estimate for the SRM's and SRM stage assembly is based on 24 stages per year for the AMLLV program and 16 stages per year for the MLLV program.

Table 3.2.3.0-I: SUSTAINING ENGINEERING MANPOWER SUMMARY FOR THE MAIN STAGE - AMLLV AND MLLV

SYSTEM		MANHOURS
STRUCTURES		143,000
FORWARD SKIRT	2,000	
ALTERNATE FORWARD SKIRT	6,000	
THRUST STRUCTURE	17,000	
LH_2 TANK	25,000	
LOX TANK (Including Common Bulkhead)	45,000	
BASE PLUG	30,000	
TUNNELS	18,000	
PROPULSION AND MECHANICAL		71,000
ELECTRICAL		35,000
INSTRUMENTATION		81,000
FLIGHT CONTROL		14,000
ASSEMBLY		103,000
	STAGE TOTAL	447,000

Table 3.2.3.0-II: SUSTAINING ENGINEERING MANPOWER SUMMARY FOR THE INJECTION STAGES - AMLLV AND MLLV

SYSTEM	2 ENGINES		4 ENGINES		6 ENGINES	
	MANHOURS					
STRUCTURES		51,624		52,812		54,000
SKIRT	1,912		1,956		2,000	
FUEL TANK	14,340		14,670		15,000	
OXIDIZER TANK	14,340		14,670		15,000	
THRUST POSTS	11,472		11,736		12,000	
TUNNELS	9,560		9,780		10,000	
PROPULSION & MECHANICAL		26,000		26,000		26,000
ELECTRICAL		10,000		10,000		10,000
INSTRUMENTATION		25,000		25,000		25,000
FLIGHT CONTROL		5,000		5,000		5,000
ASSEMBLY		27,724		28,362		29,000
STAGE TOTAL		145,348		147,174		149,000

Table 3.2.3.0-III: SUSTAINING ENGINEERING MANPOWER SUMMARY FOR THE SRM STRAP-ON STAGES - AMLLV AND MLLV

SYSTEM	AMLLV MANHOURS		MLLV MANHOURS	
STRUCTURES		21,000		21,000
NOSE CONE	5,000		5,000	
FORWARD ATTACHMENT SKIRT	7,000		7,000	
AFT ATTACHMENT SKIRT	4,000		4,000	
FITTINGS	5,000		5,000	
SRM's AND STAGE ASSEMBLY		7,409		7,028
STAGE TOTAL		28,409		28,028

4.0 DEVELOPMENT AND TEST PLAN (R&D and Recurring Tests)

This test plan is applicable to both the full size (AMLLV) and the half size (MLLV) programs. Differences in resource requirements due to variation in sizes of specimens, equipment, load requirements, etc., are noted in applicable discussions.

This test plan was developed from inputs from Boeing and NASA organizations currently performing similar activities for the Saturn V/Apollo program. These inputs were developed considering the current test philosophy for the Saturn V/Apollo systems.

Prior to the presentation of the Test Plan, test philosophies, ground rules and assumptions are outlined and discussed (Section 4.1). Supporting charts define and illustrate the test program constraints and requirements, from program go-ahead through final flight tests.

This test plan is then subdivided into two major sections to facilitate identity with the cost categories established for the costing analyses, i.e.:

Section 4.2 - Development and Qualifications Tests - Applicable to "B" cost category

Section 4.3 - Manufacturing and Operations Tests - Applicable to "C" cost category

These two major categories are then further subdivided as shown below:

a. Development and Qualification Tests (Non-Recurring Tests)

- Model Tests
- Manufacturing Mock-Up
- Facility and GSE Shakedown, "F Bird"
- Component and Subassembly Development Tests
- Breadboard Tests
- Static Load Tests
- Dynamic Tests
- Engine Development and Qualification Tests
- SRM Stage Development and Qualification Tests
- Static Firing and Flight Tests
- Ground Support Equipment (GSE) ;

b. Manufacturing and Operations Tests (Recurring Tests)

- Acceptance Tests
  - Receiving Tests
  - In-Process Tests
  - Manufacturing Checkout
- Static Firing Test
- Prelaunch Test and Checkout .

4.0 (Continued)

Schedules for accomplishment of the various tests are shown, where necessary to support the text, in the discussion of the specific tests. General test schedules, keyed to the overall program schedule are shown in subsequent Section 8.0.

4.1 TEST PHILOSOPHY, GROUND RULES AND ASSUMPTIONS

General overall philosophy, ground rules and assumptions are discussed in the next subsection. Subsequent subsections discuss major test categories and the applicable specific philosophies, ground rules and assumptions.

4.1.1 General

a. Tests will be planned for the various generation levels of hardware. Particular emphasis will be given to interactions at higher levels, which are not seen at lower levels ;

b. Cognizance will be taken of previous testing of subassemblies of subsystems. These tests will not, in general, be duplicated at higher assembly levels. Subsequent testing will cover primarily areas of new and/or increased requirements ;

c. Maximum utilization will be made of existing facilities ;

d. Tests will be conducted to the maximum extent practicable under mission environments ;

e. Assemblies and other lower levels of hardware that are vital to the life of the crew will be tested in sufficient number to yield a significant level of engineering confidence. Also, the state-of-the-art (or uncertainty) associated with certain hardware will require larger numbers of test specimens and more extensive testing in depth ;

f. All tests on systems, subsystems, major assemblies and components, and special items designated by the NASA Centers will be monitored and reviewed by cognizant Center personnel;

g. Ground tests will be utilized to minimize the number and cost of development flight tests required to produce reliable operational systems ;

h. Data from all types of tests will be used for reliability assessment ;

i. All flight hardware must be qualified and receive a Certification of Flight Worthiness before flight test.

4.1.1 (Continued)

The Test Program will be developed within the frame of the Program Plan and in accordance with the applicable program constraints of subordinate planning documentation in accordance with Figure 4.1.1.0-1.

The four major test categories are:

a. Design and Development Tests;
b. System/Subsystem Tests;
c. Qualification Tests;
d. Production Tests.

Table 4.1.1.0-I shows the vehicle components and support equipment test requirements in each of the major test categories. The objectives and constraints for each test category are discussed in the following paragraphs:

4.1.2 Design and Development Tests

Design and Development Tests consist of two general categories, i.e.:

a. Feasibility and Configuration Selection Tests — materials and process selection tests, material strength tests, thermal gradient tests and other tests determined necessary to select an optimum configuration;

b. Design Evaluation Tests — wind tunnel, structural static, dynamic, acoustic, etc., tests as required to assure that the basic design assumptions and parameters are adequate and that design engineering can be finalized and released.

The development test program does not include the design support tests required by engineering to produce a vehicle design.

The general objectives of the Design and Development Test Program are as follows:

a. Measure and assess the accomplishment of development objectives;

b. Ensure that systems and equipment meet established requirements;

c. Obtain a true indication, forecast, or verification of the actual performance capabilities of any given system, subsystem, or item of equipment in as realistic an operational environment as practicable;

d. Identify operational and engineering deficiencies in time for changes to be incorporated before significant production buildup. Ensure that changes to operational equipment meet the required objectives, or that necessary tradeoffs are identified;

e. Provide data for operational analyses and for application to 1) current and future systems and 2) system studies;

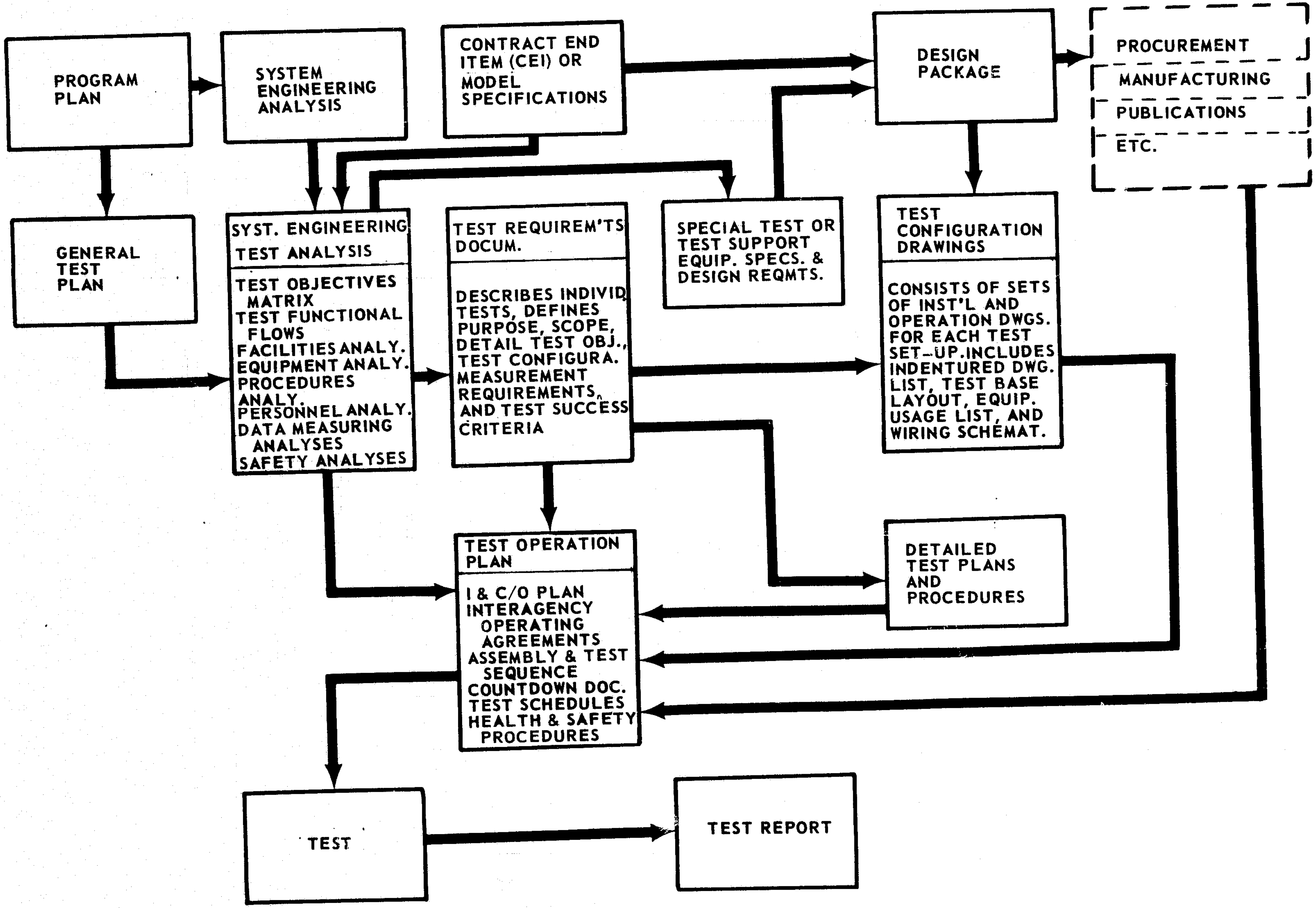


FIGURE 4.1.1.0-1 TEST PROGRAM CONTROLS AND DEFINITION

TABLE 4.1.1.0-I TEST MATRIX

	DEVELOPMENT TESTS												SYSTEM/SUBSYSTEM TEST															QUALIFICATION TESTS																	PRODUCTION TEST					
	WIND TUNNEL			STRUCTURAL			MATERIAL LAB						INTERFACE EVAL TEST					SPEC COMPLIANCE DEMONSTRATION TEST										PERFORMANCE							ENVIRONMENTAL								RELIABILITY		QUALITY VERIFICATION					
	AERODYNAMIC LOADS AND MOMENTS	STABILITY & CONTROL	DYNAMIC MODEL	STATIC LOADING	DYNAMIC	HYDROSTATIC	HIGH TEMPERATURE	THERMAL SHOCK	TEMPERATURE GRADIENT	BONDING	ACOUSTIC	ELECTRICAL ELECTRONIC	POWER SWITCHING	RFI	HANDLING	FORM AND FIT	OPERATING CHARACTERISTICS VERIFICATION TEST	STRUCTURAL DYNAMIC	ROAD TRANSPORTATION	SEA TRANSPORTATION	PRESSURE HYDROSTATIC	ACOUSTIC	SAFETY	FLIGHT PROOF	OFF NOMINAL SYSTEM OPERATION TESTS	MAINTAINABILITY & FAULT ISOLATION DEMONSTRATION TESTS	SIMULATED COUNTDOWN & FLIGHT DEMONSTRATION TESTS	STRUCTURAL DYNAMIC	STATIC	STATIC FIRING	OPERABILITY	MAINTAINABILITY	SAFETY	FLIGHT PROOF	SAND	SALT	SPRAY	TEMPERATURE	HUMIDITY	ACOUSTIC	RFI	STORAGE	FAILURE MODES	LIFE CYCLE USEFUL LIFE	LEAK RESISTANCE TESTS	COMPONENT PERFORMANCE TESTS	DESIGN PARAMETER VERIFICATION	CALIBRATION TESTS	FAI	ACCEPTANCE
SRM/T & H EQUIPMENT															X				X	X			X																											
SRM/INSTRUMENTATION															X		X						X	X																								X		
SRM/FACILITY EQUIPMENT													X	X	X	X	X						X		X	X																								
SRM/GSE																	X									X																								
COMMUNICATION SYSTEMS													X	X			X								X	X	X																							
CONTROL & DISPLAY SYSTEMS													X	X			X								X	X	X																							
ECS SUBSYSTEMS							X		X		X	X	X			X	X						X		X	X	X																							
FUEL SYSTEMS																X	X				X		X		X	X	X																							
TVC SYSTEMS											X	X	X	X	X	X	X	X				X	X		X	X	X																							
STACKED VEHICLE																											X																							
INSTRUMENTATION AND DATA ACQUISITION SUBSYSTEMS					X					X	X	X	X	X	X	X	X	X				X		X	X	X	X																							
AIRBORNE SUBSYSTEMS(ELECTRICAL)					X						X	X	X	X	X	X	X	X				X	X	X	X	X	X																							
AIRBORNE SUBSYSTEMS (MECHANICAL)					X						X				X	X	X	X				X	X	X	X	X	X																							
AIRBORNE SUBSYSTEMS (FLUIDS)					X	X					X				X	X	X	X			X	X	X	X	X	X	X																							
FUNCTIONAL CORE STAGE													X		X	X			X	X			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X		X	X	X	X
FUNCTIONAL INJECTION STAGE													X		X	X			X	X			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X		X	X	X	X
CORE STAGE/T & H EQUIPMENT															X				X	X																														
CORE STAGE/INSTRUMENTATION															X		X						X	X																								X		
CORE STAGE/FACILITY EQUIPMENT													X	X	X	X	X						X		X	X				X																				
CORE STAGE/GSE																	X									X																								
INJECTION STAGE/T & H EQUIPMENT															X				X	X																														

SHEET 1 OF 2

TABLE 4.1.1.0-I TEST MATRIX

	DEVELOPMENT TESTS												SYSTEM SUBSYSTEM TEST															QUALIFICATION TESTS																	PRODUCTION TEST					
	WIND TUNNEL			STRUCTURAL			MATERIAL LAB						INTERFACE EVAL TEST					SPEC COMPLIANCE DEMONSTRATION TEST										PERFORMANCE							ENVIRONMENTAL								RELIABILITY		QUALITY VERIFICATION					
	AERODYNAMIC LOADS AND MOMENTS	STABILITY & CONTROL	DYNAMIC MODEL	STATIC LOADING	DYNAMIC	HYDROSTATIC	HIGH TEMPERATURE	THERMAL SHOCK	TEMPERATURE GRADIENT	BONDING	ACOUSTIC	ELECTRICAL ELECTRONIC	POWER SWITCHING	RFI	HANDLING	FORM AND FIT	OPERATING CHARACTERISTICS VERIFICATION TEST	STRUCTURAL DYNAMIC	ROAD TRANSPORTATION	SEA TRANSPORTATION	PRESSURE HYDROSTATIC	ACOUSTIC	SAFETY	FLIGHT PROOF	OFF NOMINAL SYSTEM OPERATION TESTS	MAINTAINABILITY & FAULT ISOLATION DEMONSTRATION TESTS	SIMULATED COUNTDOWN & FLIGHT DEMONSTRATION TESTS	STRUCTURAL DYNAMIC	STATIC	STATIC FIRING	OPERABILITY	MAINTAINABILITY	SAFETY	FLIGHT PROOF	SAND	SALT	SPRAY	TEMPERATURE	HUMIDITY	ACOUSTIC	RFI	STORAGE	FAILURE MODES	LIFE CYCLE USEFUL LIFE	LEAK RESISTANCE TESTS	COMPONENT PERFORMANCE TESTS	DESIGN PARAMETER VERIFICATION	CALIBRATION TESTS	FAI	ACCEPTANCE
INJECTION STAGE/INSTRUMENTATION														X	X		X							X	X																							X		
INJECTION STAGE/FACILITY EQUIPMENT													X	X	X	X	X							X		X	X																							
INJECTION STAGE/GSE																	X										X																							
SRM															X				X	X	X						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						X	X	X
MECHANICAL COMPONENTS/ASSEMBLIES				X	X		X	X	X	X	X				X	X	X					X						X	X		X	X	X	X	X	X	X	X	X	X		X	X	X		X	X		X	X
ELECTRICAL COMPONENTS/ASSEMBLIES				X	X		X	X	X	X	X	X	X	X	X		X					X			X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ENGINE COMPONENTS				X	X	X	X	X	X	X	X				X	X	X				X	X						X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
CABLING, PIPING, ETC.					X	X						X				X					X							X	X				X	X						X	X				X				X	X
INSTRUMENTATION ASSEMBLIES					X		X	X	X	X	X	X	X	X	X	X	X	X				X	X	X		X												X	X	X	X		X	X		X	X	X		X
AIRBORNE STRUCTURE	X	X	X	X	X		X	X	X	X	X																	X	X	X			X	X	X	X	X	X	X	X				X					X	X
SUPPORT AND ALIGNMENT EQUIPMENT												X				X												X	X		X	X	X		X	X	X	X	X	X		X	X	X		X	X	X		X
FACILITIES EQUIPMENT				X	X		X	X	X		X	X	X	X		X	X	X			X	X	X			X	X	X	X		X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
SERVICE ARMS				X	X		X	X	X		X														X	X		X	X		X	X	X		X	X	X	X	X	X			X	X			X	X	X	X
TRANSPORTATION & HANDLING EQUIPMENT				X	X											X	X	X	X	X			X		X	X		X	X		X	X	X		X	X	X	X	X			X	X	X			X	X	X	X
ELECTRO-MECHANICAL SUBSYSTEMS				X	X		X	X	X		X	X	X	X	X	X	X	X			X	X	X	X	X	X	X																							
ELECTRICAL POWER SUBSYSTEMS					X			X	X			X	X	X	X	X	X	X				X	X	X	X	X	X																							
FLUID SUBSYSTEMS						X					X				X	X	X	X			X	X	X	X	X	X	X																							
PROPULSION SUBSYSTEMS	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X			X	X	X	X	X	X	X		X																					
GUIDANCE & CONTROL SUBSYSTEMS					X						X	X	X	X	X	X	X	X				X		X	X	X	X																							

SHEET 2 OF 2

4.1.2 (Continued)

f. Verify the overall logistic capability, scope, and effectiveness as prescribed by appropriate support procedures, plans, and planning factors, developed concurrently with system evolution. Acquire and evaluate data to:

1. Verify and refine logistic procedures, plans, and planning factors,

2. Enhance prospective support planning,

3. Identify areas which will require additional impetus to ensure integrated effective system(s) logistic support.

g. Assess identified manpower, space, and personnel resources necessary to support systems and equipment;

h. Validate training and training programs;

i. Obtain data and evaluate safety and reliability of systems, subsystems, or items of equipment in severe and abnormal environments such as fire, lightning, explosion, severe impact, extreme pressure or temperature changes, radiation, electromagnetic radiation, or combinations of these conditions;

j. Determine the performance, reliability, and integrity of individual Government Furnished Equipment (GFE) in the environments imposed by this system;

k. Identify the preliminary performance, operating characteristics and qualitative adequacy of the system, subsystem, and end items;

l. Determine the preliminary compatibility, adequacy, supportability, reliability, and electromagnetic compatibility of associated ground equipment (AGE), training devices, ground communications-electronics meteorological equipment, commercial ground communications-electronics, computer equipment and programs;

m. Determine the preliminary maintainability and transportability characteristics of components, subsystems and contract end items;

n. Determine the preliminary validity of personnel and training planning information. This information is used for personnel skill identification, development of manning documents, training, training equipment requirements, and additional requirements to ensure personnel and training support. When feasible, formal training will be evaluated by applicable procedures;

o. Establish the preliminary identification and investigation of safety criteria for the system, subsystem, and any necessary safety programs, before initial operational capability is established. This should include testing in predictable operational environments;

4.1.2 (Continued)

p. Define the data necessary for preliminary system operating procedures, handbooks, technical manuals;

q. Determine the adequacy of new design or updating changes;

r. Determine the adequacy of preliminary health hazards data and precautionary information;

s. Define the procedures for the prevention of and recovery from potentially catastrophic situations;

t. Determine the preliminary vulnerability/survivability characteristics of components and subsystems in extreme environments.

4.1.3 System/Subsystem Tests

This program consists of testing and evaluation spanning the integration of subsystems into a complete system, and development tests of the completed system in as near an operational configuration and environment as practicable. Suitable instrumentation will be employed to determine the functional capability and compatibility of subsystems. The minimum test requirements are:

a. Use of hardware representative of flight hardware;

b. Use of GSE representative of equipment to be used at the launch site;

c. Retest when significant hardware changes are made which invalidate results of previous tests.

Systems tests may be a combination of development test and ground qualification test.

The system/subsystem tests will be conducted to:

a. Determine that the system contract end-items meet established requirements and specifications for performance, control, maintenance, safety, and reliability;

b. Define the operational configuration;

c. Determine, develop, and test updating changes that are necessary to meet approved performance requirements;

d. Determine that the subsystems within stages and modules are physically and functionally compatible;

4.1.3 (Continued)

e. Determine the functional compatibility between stage and module subsystems and the ground support equipment;

f. Refine logistic procedures and policies;

g. Verify required technical data. This term is interpreted in its broadest scope, and includes prints, drawings, handbooks, manuals, technical documents, and other related publications;

h. Evaluate new design changes, including computer programs before they are incorporated into the production system;

i. Determine system capabilities, limitations, safety characteristics, and vulnerability/survivability characteristics under actual or simulated operating conditions by ground and flight tests (as appropriate). These tests are designed to yield both engineering and technical manual data;

j. Provide familiarization, experience, and training to supporting operating personnel;

k. Demonstrate with trained personnel, authorized equipment, spares, and technical data, that the complete system is operable, maintainable, and transportable (as appropriate);

l. Verify that personnel performance is adequately supported by training devices, equipment design, tools, technical data, job environment, training, personnel selection criteria, manning, and organizational control procedures;

m. Demonstrate that the system will perform in its intended environment without degrading itself or other systems.

Test and Evaluation will not be considered completed until performance requirements as defined in the system performance/design requirements specification and associated contract end item specifications have been met, and it has been demonstrated that the system can be operated and maintained using authorized equipment, trained personnel, preliminary system operating procedures and technical data.

4.1.4 Qualification Tests

The Qualification Program is required to verify that the space vehicles and associated ground support equipment meet design specification requirements necessary to assure operational suitability at anticipated environments for their use cycles.

Minimum qualification test requirements are as follows:

4.1.4 (Continued)

a. Ground qualification tests and specific ground tests shall be performed on a sample of flight type production hardware in accordance with the preceding Table 4.1.1.0-I;

b. All tests specified in the preceding Table 4.1.1.0-I will be successfully completed on mission critical ground support equipment. Such successful completion will comprise the qualification of the ground support equipment;

c. Certain special tests such as burst tests to verify that hardware does not fail below proof limits shall be performed as required to assure operational safety.

Acceptance tests through manufacturing checkout shall be performed on hardware prior to its being subjected to qualification tests. The acceptance tests shall be identical to the acceptance tests performed on flight hardware or operational GSE, including the vigorous inspection imposed thereon. Additional qualification test time (or cycles) will be accumulated on test specimens to account for that portion of the functional life cycle to be encountered during acceptance tests prior to mission use.

Qualification tests shall be performed on production hardware under strict control of environments and procedures. Revisions to procedures, adjustments, or tuning is not permissible during the course of a test unless it is normal to the in-service operation. If such action becomes necessary, the test specimen shall be disqualified pending corrective action. Hardware that has been subjected to ground qualification tests shall not be utilized on flight vehicles. It may, however, be utilized for reliability demonstration tests. The qualification test report shall state the disposition of the qualification units.

Any failure of test specimen shall disqualify the entire class of hardware (all items of hardware made to the same specifications and intended for the same specification as the qualification hardware). Where a failure occurs, hardware or procedural changes shall be introduced into all test hardware and the qualification test shall be reinitiated. However, if the cause of failure is a quality defect which can be detected by a nondestructive inspection, then those units of the sample which have already been tested without failure need not be retested. Nevertheless, all units must perform without failure, including the retested units for which defects have been corrected. In the above cases, extreme caution shall be taken to assure that these changes and corrections are made to all units in the class and that such action will not degrade the units.

Hardware shall be subjected to requalification tests:

a. When design or manufacturing process changes have been made which affect functioning or reliability;

b. Where inspection, test, or other data indicate that a more severe environment or operating condition exists than that to which the equipment was originally tested;

4.1.4 (Continued)

c. When the manufacturing source is changed.

Qualification tests consist of four types of tests, i.e.:

a. Performance Tests;
b. Environment Tests;
c. Reliability Tests;
d. Flight Proof Tests.

Performance Tests will be performed to prove compliance with performance specifications. Typical testing in this category shall be tests which require hardware functioning before, during, and after application of dynamic loading and acoustics; static testing in both destruct and nondestruct categories; RFI, and electromagnetic interference tests; etc.

Environment Tests shall be performed to prove compliance with specified environmental criteria. Typical testing in the category include humidity, sand, dust, salt spray, temperature, etc.

Reliability Demonstration Tests will be conducted to establish a significant level of engineering confidence in the reliability of the hardware. Reliability Demonstration Tests will be performed on flight type hardware in accordance with the prior Table 4.1.1.0-I. These tests will be a continuation of qualification tests to verify the life expectancy, with the addition of over-stress tests as necessary to determine failure modes and safety margins.

The reliability test is a section of the qualification test conducted on equipment under conditions as closely approximating service conditions as practicable, for the purpose of eliminating gross design deficiencies.

The overall reliability test program shall be established utilizing a carefully prepared evaluation of environment and performance with respect to vehicle operating time, cycles, etc., for the anticipated usage of the particular equipment. The tests shall be designed to simulate as closely as practicable the operation of the equipment in service. Where possible, combined environments shall be used in performing the tests. Where overloads or other extreme conditions are actually expected to occur, tests for these conditions shall be included but only to the minimum extent required.

Reliability testing shall be limited to the testing of those requirements which are either critical to the operation of the equipment, or which will reveal the maximum information about the performance of the equipment in service. The mean time (or cycles) between failure design objective will be confirmed to a varying degree dependent upon the particular tests which are defined in each specification. In some cases, results of tests other than the reliability tests can be used as evidence of meeting the reliability objective.

4.1.4 (Continued)

Flight test will be the final demonstration of the airborne system compliance with the system specification. The flight test program is discussed in detail in Section 7.0 of this document.

4.1.5 Production Tests

Production Tests include:

a. Test firing (static firing) each stage to demonstrate acceptability of the stage-engine combination;

b. Prelaunch checkout to verify readiness for operation;

c. Verifying that the delivered product is manufactured per drawing and specification and will operate within acceptable tolerances.

Factory and prelaunch test and checkout should be accomplished as much as possible by on-board test and checkout equipment reporting to a ground-based computer. An on-board test and checkout computer may also be required. The demands of a vehicle of this size and type of mission dictate that all flight and checkout equipment necessary for successful launch and mission accomplishment be redundant.

4.1.6 Test Category Relationship to Specific Type Tests

The four major test categories defined above are not readily discernable in an overall test plan,as the specific test requirements for a major test category are often combined with those of another major category to define the test requirements for a specific type test. Similarly, a specific type test may be applicable to all of the test categories at some time in the program. For example, initial static firing tests of the assembled stage are applicable to the Development and Qualification Test Categories, while later firings are applicable to the Production Acceptance Test category.

Because of the above test program interactions and iterations and because of the requirements for this study to determine both nonrecurring and recurring test costs attributable to the component level, subsequent paragraphs will discuss specific type tests rather than test categories.

4.2 DEVELOPMENT AND QUALIFICATION TESTS

Development tests are performed to assure the proper functioning of the components of the system. Specific test objectives include: determination of feasibility of design approach, evaluation of hardware performance under simulated or actual environmental conditions, and evaluation of hardware failure modes and safety factors.

Qualification tests are performed to verify that the vehicle and ground support equipment conform to the design specifications. The specification requirements are necessary to assure operational suitability.

4.2 (Continued)

Sections 4.2.1 through 4.2.11 provide descriptions of specific tests or test categories. Resource requirements for each of the specific tests or test categories are given, where possible, in terms of 1) the facility equipment and tools required for the testing activity, and 2) the manpower, materials and test specimens required during the course of the testing activity.

4.2.1 Model Tests

Models will be used in wind tunnel tests to investigate the aerodynamic characteristics and dynamic behavior of the AMLLV/MLLV under laboratory conditions.

4.2.1.1 Test Description

Force Model Tests — The purpose of these tests will be to ascertain range safety aerodynamics after inflight destruct, by checking the aerodynamic characteristics of models of selected fragments of the liquid stages and solid motors.

AMLLV/MLLV Base Heating Model Tests — Supersonic and transonic tests will be conducted. The tests will include heating and pressure measurements in the base region for the range of possible configurations and anticipated flight environments.

Separation Tests — These tests will investigate the aerodynamic characteristics and dynamic behavior during separation of the 260" SRM strap-ons from the main stage, and the separation of the main stage from the injection stage.

Performance Characteristics of Various Vehicle Combinations — Model tests will determine aerodynamic performance characteristics of possible vehicle configurations within the vehicle family.

4.2.1.2 Resource Requirements

The assumption is that adequate facilities already exist for the conduct of the model tests to develop the required information for the AMLLV/MLLV programs. It is anticipated, therefore, that costs for these tests will be based on procurement of the models and occupancy time at the test facility. The required resources (costs) for the AMLLV and MLLV programs should be identified.

Based on prior test experience, the following estimates were made:

Single-Stage-to-Orbit Vehicle Model Tests	- $600,000
Additional Model Test Costs Attributable to Adding Injection Stage	- NONE
Additional Model Test Costs Attributable to Adding SRM Stages	- $400,000

4.2.1.2 (Continued)

These estimates represent the total cost to the program for the model tests. No costs were attributed to the Instrument Unit (I U).

4.2.2 Manufacturing Mock-Up

Extensive use of manufacturing mock-ups is planned to aid in the development of main stage and injection stage manufacturing tooling and techniques. These mock-ups will be limited to system and subsystem, assembly and subassembly levels because of the sizes and weights involved. Mock-ups will be provided for the main stage and for the engine module of the injection stage.

No mock-ups are planned for the injection stage fuel modules or for the SRM stages. As the vehicles will use a modified Saturn V Instrument Unit, no mock-up will be provided for the Instrument Unit. The estimates for the MLLV main stage mock-up were determined to be identical to actuals for the S-IC stage mock-up. The inert weight of the S-IC stage and the MLLV main stage is approximately the same, and both stages have relatively the same numbers of different components and subsystems. The estimates for the AMLLV main stage were obtained by multiplying the MLLV estimates by the ratio of AMLLV main stage production costs to MLLV main stage production costs.

The estimates for the injection stage engine module mock-up were obtained by taking 25 percent of the main stage mock-up estimates. This ratio was derived by considering the weight and system complexity differences between the main stage and injection stage. Miscellaneous costing factors were added to these direct resource estimates, to define the total test costs shown below.

	AMLLV	MLLV
MAIN STAGE	$5,038,000	$3,176,000
INJECTION STAGE (ENGINE MODULE)	$1,258,000	$793,000

4.2.3 Facility, GSE and Tooling Shakedown Tests ("F" Vehicle)

Production, test and launch procedures, tools, equipment and facilities must be validated before use. The primary objective is to achieve a state of operational readiness prior to processing flight stages.

The tests will provide design verification and compatibility of stage systems, GSE, and facilities to validate and improve technical operating procedures, i.e.:

a. Functional test and calibration of tooling GSE, and facilities;

b. Overall checkout to demonstrate compatibility with stage systems;

c. Manual and automatic checkout of individual and integrated systems to accomplish prefiring checkout and to monitor and control a countdown and static firing (simulated);

d. Verify stage receiving, transporting and handling equipment and procedures.

A facilities checkout vehicle ("F" vehicle) will be fabricated and utilized to accomplish these objectives.

GSE at the factory checkout facility will be as nearly identical as possible to that used at the static firing facility and for prelaunch and countdown. The configuration of the checkout stages will be generally identical to flight stages. The "F" checkout stage will be of flight configuration size and contain stage systems sufficient to support a facility validation test regime short of an engine test run.

Component level testing of GSE (and GSE instrumentation calibration) and basic facilities checkout, or other special testing, will have been completed prior to introduction of the "F" vehicle.

4.2.3.1 Test Description

Factory Checkout — The factory facilities include all those facilities, at whatever site, required to produce vehicle components, subassemblies and assemblies. Production of the "F" vehicle components will serve as the test of the suitability of the designated procedures, tooling, equipment and facilities to produce compatible vehicle components. These facilities will include those necessary test cells required for delivery of acceptable components and assemblies, and those elements required for handling and transportation. Validation testing of the factory will start with a functional test and a preliminary verification of calibration procedures and proceed through fabrication, test and delivery of vehicle hardware.

The components, subassemblies, assemblies, etc., will be incorporated to make up the individual stages of the "F" vehicle. Transportation and handling equipment will be used (and the procedures verified) to handle the completed test stages. There shall then be a physical fit check performed between the completed checkout stages,

4.2.3.1 (Continued)

the facility, and GSE. A stage individual systems check shall be performed, followed by an integrated checkout of facility and stage systems to complete validation of the facility, GSE, GSE calibration procedures, and stage test procedures. Transportation and handling equipment will be used (and the procedures verified) to remove the test stage.

Dynamic Test Facility — The "F" stages, the "F" instrument unit (IU) and the simulated payload will be used to check out the dynamic test facilities and handling equipment for form, fit and operability. (SRM stage loads will be simulated by vibrational loading at the SRM stage attach points to the core stage, so that SRM stages are not needed.) Assembly and handling procedures will be prepared to evaluate vehicle handling and assembly methods using the "F" stages for vehicle assembly. Particular care will be used to ensure that these procedures are fully coordinated with all organizations involved in planning stage and vehicle handling, and assembly.

Static Firing Facility Checkout (Launch Facility) — The launch complex will be adapted for stage static firing tests as well as vehicle launch. Using the "F" stages, manual and automatic pre-firing checkout, and a countdown and static firing (simulated) of the checkout stage will be accomplished.

Validation testing of the static checkout facility (launch facility) will start with a functional test and calibration of GSE, facility, and technical systems at the subsystem level. Stage substitutes will be used to perform a complete stage systems check, followed by an overall checkout of the test complex to verify compatibility between facility and stage systems. Transportation and handling equipment will be used (and the procedures verified) to install a test stage. Connection will then be made to the stage pneumatic, fuel and hydraulic lines, electrical power, and data acquisition equipment. A stage-to-test-stand fit check will be performed to verify compatibility between GSE, test stand, the stage and each other. The test and checkout equipment will then be used to manually and automatically perform a stage individual and integrated systems check, followed by a countdown and a simulated static firing of the test stage. Data will be reduced and evaluated to establish validation of the launch complex to process flight stages through the static firing phase.

Costs of the "F" vehicle test and checkout program at the dynamic test facility will be allocated to the dynamic test facility activation. Paragraph 4.2.7 describes and discusses the dynamic test program.

Launch Complex Checkout — The checkout of the Launch Complex will afford the most comprehensive test attainable on the AMLLV/MLLV program, short of vehicle flights. Significant flight hardware, GSE, procedures, personnel, organization, and supporting services will be integrated for the first time as an operational entity, and proved under conditions closely simulating prelaunch activity and environment. The complex will be in its operational configuration for the subject checkout. The primary objective of the launch complex checkout will be to achieve a state of launch complex operational readiness to receive, process, launch, and support flight for the vehicle. A description of the launch complex appears in Section 7.0.

4.2.3.1 (Continued)

The preceding static firing checkout and verification of facilities and equipment will already have accomplished the intent of a portion of the following test requirements. This test is a continuation of design verification of the launch vehicle systems and structure and will:

a. Verify that GSE and facilities provided for AMLLV/MLLV ground operations are physically and functionally compatible with the launch vehicle and with each other;

b. Verify that GSE is compatible with range tracking, guidance, telemetry, and safety systems;

c. Verify that the complex ground communications are compatible with range networks;

d. Verify that operational procedures are adequate to support prelaunch operations;

e. Monitor and evaluate operational integrity of launch vehicle systems under simulated operational conditions;

f. Train and qualify technical personnel to support prelaunch operations;

g. Evaluate and improve supporting services attendant to vehicle processing, including logistical support.

Complex checkout will duplicate flight vehicle and facility processing planned for prelaunch and launch operations as closely as possible. Test procedures for prelaunch operations will be used to perform complex checkout operations. Procedural deviations necessary to accommodate test peculiarities of complex checkout will be identified as such within the test procedures.

GSE hardware will be tested and retested, if necessary, until this equipment is acceptable for support of the first flight vehicle; however, retesting for purposes of improving procedures will be avoided.

The facility checkout vehicle ("F" vehicle) will arrive at the launch complex in individual, but complete, stages.

All hardware on the facility checkout "F" vehicle which is of flight configuration will be treated as though it were installed on a flight vehicle. This treatment will include protection from abuse, prescribed maintenance, configuration control, and monitoring for design adequacy.

Complete instrumentation calibration on all GSE is a prerequisite for GSE Readiness Tests. All real time displays shall be calibrated on site. End to end calibration will be conducted if possible.

4.2.3.2 Resource Requirements

The Facilities Checkout Vehicle ("F" vehicle) will consist of a main stage and a simulated payload with an instrument unit plus injection stage module(s) and/or an inert SRM stage where applicable. All liquid stages of the vehicle will have propellant loading capability, stage mating interfaces, and the structural integrity required for erection and fueling. The exterior of the vehicle will include those flight configuration geometries which require specific physical clearance from facilities and GSE. The dry weight and C.G. of the "F" vehicle and the individual stages will be within 10 percent of flight configuration.

The configuration of the "F" vehicle will limit its capacity to checkout the Launch Complex to evaluation of the following functions:

a. Stage and vehicle handling equipment and procedures;

b. Propellant loading equipment and procedures;

c. Pneumatic servicing equipment and procedures;

d. Launch vehicle mechanical and physical compatibility with launch complex facilities and GSE.

This vehicle will be assembled from facility checkout versions of the various stages in the same manner as flight vehicles will be assembled. Deviations from the flight article designs of the various stages and IU will be as follows:

a. "F" Vehicle Main Stage - This stage will not include:

1. Heat shield curtains,
2. Fuel feed lines,
3. Engines,
4. Engine heat exchangers,
5. Hydraulic system,
6. Live ordnance.

Oxidizer feed lines will be limited to those required for fill and drain. Dummy engines, dimensionally and weight simulated, will replace the flight engines. The electrical systems and components will be limited to those required for propellant servicing, pressurization and environmental control system operation. Dummy ordnance items will replace the live ordnance.

Instrumentation on the stage will be confined to measurement of specific parameters on the pneumatic service system and environmental control system.

b. "F" Vehicle Injection Stage - This stage will not include:

4.2.3.2 (Continued)

1. Oxidizer feed lines and prevalves,
2. Fuel feed lines and prevalves,
3. Chilldown purge system,
4. Heat shield,
5. Flight engines,
6. Heat exchangers,
7. Hydraulic power system.

This stage will be equipped with that portion of the flight electrical system required to operate control pressure, fuel pressurizing, propellant fill and drain, oxidizer pressurizing, and propellant utilization. Dummy ordnance items will replace live ordnance.

c. "F" Vehicle Instrument Unit - The Instrument Unit will not include:

1. Mechanical components except umbilical plate,
2. Flight type electrical components,
3. Flight instrumentation.

d. Simulated Payload — The spacecraft will be a flight-similar mockup.

e. SRM Stage — One solid rocket motor stage (inert propellant) will be provided to checkout SRM transportation and handling equipment, and the launch pad SRM handling and assembly operations.

Elimination of the "F" vehicle would not substantially reduce the resource requirements for checkout of the procedures, tooling, GSE and facilities. These activities would still be required. The "F" vehicle is essentially a tool for accomplishing these tests.

Factory Checkout — The resource requirements for facility, GSE and tooling checkout were estimated as follows. As the facilities, equipment and tooling required for the "F" vehicle will also be required for production and launch of operational hardware, no requirements for these elements were attributed to these tests.

The manpower and material estimates for manufacture of the main and injection stages of the "F" vehicle were obtained from the first unit production estimates for the various stage elements (Section 5.0). For example, the estimates for the "F" vehicle main stage were assumed to be equivalent to the requirements attributable to production of one set of operational main stage structure plus one-fourth (1/4) set of main stage systems. Costing factors were applied to these estimates to define the total costs for checkout of the manufacturing facility, GSE and tooling. Costs for the inert SRM were estimated from first unit production costs, assuming re-use of R&D hardware. The resulting costs for manufacture of the "F" vehicle components and the checkout costs for the manufacturing facility, GSE and tooling are shown below:

4.2.3.2 (Continued)

	AMLLV	MLLV
Single-Stage-to-Orbit Vehicle Configuration (With Payload and IU)	$55,054,000	$40,993,000
Additional Requirements for Injection Stage (Engine Module)	$13,041,000	$9,752,000
Additional Requirements for SRM Stage (1 Dummy) (Includes Requirements for Larger Payload Shroud and for Heavier Main Stage Forward Skirt	$10,215,000	$7,093,000
Additional Requirements for each Add-On Injection Stage Fuel Module	$7,644,000	$5,221,000

Dynamic Test Facility Checkout — The requirements for checkout of the dynamic test facility were charged against the resource requirements for dynamic testing. No requirements were, therefore, attributed to the "F" vehicle during checkout of the dynamic test facility.

Transportation Checkout — The transportation checkout resource requirements of the "F" vehicle were defined and combined with costing factors to determine the total program costs for transportation of the "F" vehicle, and checkout of transportation equipment. Below are the "F" vehicle transportation and checkout costs.

	AMLLV	MLLV
Main Stage		
Barge Maintenance for one-half Year	$ 45,000	$ 45,000
Towing Services	$ 35,000	$ 35,000
One-Half Year Maintenance of Land Transporter and Tow Vehicle	$ 4,000	$ 4,000
Injection Stage (Independent of No. of Modules)		
Barge Maintenance for one-half Year	$ 20,000	$ 20,000
Towing Services	$ 16,000	$ 16,000
One-Half Year Maintenance of Land Transporter and Tow Vehicle	$ 3,000	$ 3,000

4.2.3.2 (Continued)

	AMLLV	MLLV
SRM Stage		
Barge Checkout and Transport of Set Attach Hardware From Michoud to Dade County (SRM contractors site)	$ 17,000	$ 17,000
Barge Checkout and Transport of Assembled Inert SRM Stage to Launch Facility	$12,700	$9,100

Launch Facility Checkout — The resource requirements for launch facility, GSE and tooling checkout were estimated as follows. The operations required for "F" vehicle processing at the launch facility were assumed to be equivalent to those required for processing the first flight test vehicle (Section 4.2.10), even though the "F" vehicle time at the launch facility is one year rather than nine months. (Manpower build-up during "F" vehicle testing was assumed.) The direct estimates for these tests were combined with costing factors to provide the following total program costs for launch facility checkout.

	AMLLV	MLLV
Single-Stage-to-Orbit Vehicle Configured With Payload and IU	$264,150,000	$246,459,000
Additional Requirements for Injection Stage (Engine Module)	$17,260,000	$15,421,000
Additional Requirements for SRM Stages (1 Dummy) (Includes Requirement for Larger Payload Shroud, and for Heavier Main Stage and Forward Skirt)	$24,291,000	$23,100,000
Additional Requirements for each Add-On Injection Stage Fuel Module	$8,994,000	$7,892,000

Overall Checkout Costs — Summing the above program costs for factory, transportation and launch facility checkout provided the following overall costs to the program attributable to the "F" vehicle.

	AMLLV	MLLV
Single-Stage-to-Orbit Vehicle Configured With Payload and IU	$319,288,000	$287,536,000
Additional Requirements for Injection Stage (Engine Module)	$30,340,000	$25,212,000

4.2.3.2 (Continued)

	AMLLV	MLLV
Additional Requirements for SRM Stages (Includes Requirement for Larger Payload Shroud, and for Heavier Main Stage and Forward Skirt)	$34,535,700	$30,219,100
Additional Requirements for each Add-On Injection Stage Fuel Module	$16,638,000	$13,113,000
Totals for Full Size Vehicles With 3-Module Injection Stages and SRM Stages (1 Dummy each).	$417,439,700	$369,193,100

4.2.4 Component and Subsystem Development Tests

In addition to the major tests (structural, dynamic, flight, etc.) that are discussed elsewhere in Section 4.2, there will be a large number of other required R&D tests for vehicle subsystems and components. Development tests of vehicle subsystems and components must be performed to assure the proper functioning of the components of the system. Specific test objectives will include: Determination of feasibility of design approach, evaluation of hardware performance under simulated or actual environmental conditions, and evaluation of hardware failure modes and safety factors.

4.2.4.1 Test Description

Component development tests will be integrated throughout the R&D program with major assembly and system test development programs. This integrated testing will not, however, preclude the requirement for the development and qualification of the subsystems and components. It was not possible to define all of the specific tests that fall within this category. Resource requirements for this general category were estimated in terms of overall program costs by applying historical factors to the overall costs of producing the first flight article.

The area of acoustics testing will present a definite problem for the large AMLLV/MLLV type vehicles and is, therefore, treated in some detail below.

Acoustics Testing — Achieving laboratory test noise decibel levels equivalent to the predicted environments of the study vehicles (above 175 db for some components) will exceed the state-of-the-art for noise generators and facilities.

Structural qualification for very high acoustic levels (above 165 db) can possibly be accomplished at lower db levels by longer duration tests. This approach was used on the S-IC fins. Acoustic qualification requirements were established at 169 db, but the test was accomplished at 163 db.

4.2.4.1 (Continued)

The following test approach for high level acoustic test for the AMLLV/MLLV components and structures is proposed:

a. Choose representative structure or components;

b. Perform low level laboratory excursion tests to determine dynamic response, strain levels, linearity of response;

c. Fatigue test at maximum level of facility (assuming that it is less than required) for extended periods of time to assess fatigue strength;

d. Instrument panels and place near a static test firing stand when tests are scheduled. The appropriate engine and specimen position must be previously selected.

It is expected that static test of certain engines will provide acoustic levels over 170 db OASPL with a desirable spectrum shape. "Piggyback tests", as proposed in (d) above, can provide structural response data on specimens which would ordinarily require extremely costly special test facilities and noise generator development.

4.2.4.2 Resource Implications

The subsystems and components of the vehicle configurations were identified but not defined in enough detail to determine the required detailed tests. The test categories listed above are examples of these unidentifiable tests, and could be extended in considerable detail. The costs for some of these tests are normally included in the purchased price of the subsystems and components. Costs for other of these tests are incurred at the prime contractors facility or through additional funding to the vendor for tests at his facility.

Boeing historical data relative to research and development testing of components and subsystems for other programs, prior to and inclusive of the S-IC program, were used as a basis for factoring cost estimates for the AMLLV/MLLV program. The following table shows the resulting total program cost estimates for component and subsystems tests for the main and injection stages of the vehicle. This table also shows estimates for the testing of SRM stage components and subsystems as supplied by Aerojet-General. These latter tests are further detailed in the section on SRM stage test costs (Section 4.2.9).

	AMLLV	MLLV
Main Stage	$150,000,000	$120,000,000
Injection Stage	$ 25,000,000	$ 20,000,000
SRM Stage	$ 34,684,000	$ 33,037,000
TOTALS	$209,684,000	$173,037,000

4.2.4.2 (Continued)

The relationship of component and subsystem test costs, between the AMLLV and the MLLV main and injection stages as shown, is the same as the relationship for production cost between the AMLLV stages and the MLLV stages.

4.2.5 System Development Breadboard Facility (SDBF)

The Systems Development Breadboard Facility will provide for extensive testing, evaluation, and verification of components, subsystems, and systems under controlled conditions that approximate those at the launch site.

The primary objectives of the development breadboard will be:

a. To provide for system development and evaluation of computer controlled checkout of the AMLLV/MLLV Electrical Support Equipment (ESE);

b. To develop and prove checkout techniques, procedures and displays;

c. To provide a basis for maintainability analysis;

d. To provide personnel familiarization and training;

e. To provide a facility where changes and modifications to the vehicle and computer controlled electrical support equipment (ESE) may be evaluated;

f. To design and evaluate many parts of the computer programs required for the checkout and launch site operations;

g. Provide support to operational personnel at the launch site by being available to investigate any problem that may arise after the flight vehicle has been delivered to the site;

h. Electrical Simulation.

The SDBF will be used to verify the AMLLV/MLLV Automation Plan, and the adequacy of the LVGSE during test operations. All LVGSE allocated to SDBF that is common to that delivered to the Launch Complex will be representative quality hardware that has met all specified test requirements. When the facility is completely operational, it will be able to simulate, or be the electrical equivalent of, the following systems:

a. The AMLLV/MLLV vehicle;
b. The interface between the vehicle and the spacecraft;
c. The interface between the vehicle and the Launch Umbilical Tower (LUT);
d. The Launch Umbilical Tower;
e. The Launch Control Center (LCC).

4.2.5 (Continued)

By the inclusion of a Mechanical Automation Breadboard (MAB), the breadboard will provide for a physical interface with the major mechanical systems and flight stages involved. In addition to serving as an integral portion of the breadboard, a number of functions have been identified which will be unique to the MAB portion, i.e.:

a. Proof of the automated mechanical checkout concept;
b. Checkout of the stage-peculiar mechanical GSE;
c. Complete checkout of the malfunction detection system.

4.2.5.1 Test Description

The systems development breadboard as indicated will include launch-oriented ground support equipment as well as stage systems. (In order for total operation to closely approximate launch site operation, certain simulators will be required.) By utilizing flight configuration hardware and GSE, operating in the normal mode, wherever possible, the MAB will provide the systems development breadboard with a far more realistic stage substitute than could be obtained through use of simulators alone.

As a minimum, systems compatibility tests shall provide reasonable assurance that:

a. Stages, modules and launch vehicle (for the specific configurations to be flown) are functionally and operationally compatible (including electromagnetic compatibility prior to shipment of the first flight stages and modules to the test site);

b. Stages, modules, or space vehicle are compatible with ground support equipment (including checkout and calibration equipment) at a manufacturing plant, static firing test area, and the launch area prior to shipment of the first flight hardware (for the specific configuration to be flown) to the above areas.

4.2.5.2 Resource Requirements

Existing facilities at Michoud will be used to house the breadboard. (A new facility for this activity would cost approximately $750,000.) The equipment for these tests will primarily consist of the elements of vehicle and GSE hardware and/or simulators that make up the breadboard plus the computer complex.

Equipment costs attributable to the Saturn V breadboard at MSFC are approximately $70,000,000. Operational costs per year are estimated at $4,300,000. The half size MLLV vehicle consisting of the main stage plus a three-module injection stage less the eight SRM stages is similar in terms of size, quantity and complexity of subsystems. The anticipated equipment cost and operational cost for this configuration were, therefore, assumed to be equivalent to the above Saturn V approximated

4.2.5.2 (Continued)

actuals. To define total operating costs, it was assumed that the AMLLV/MLLV breadboard would be in use for five years.

To allocate costs to the various MLLV configuration elements, as shown in Table 4.2.5.2-I, the following procedure was used. Main stage (single-stage-to-orbit) costs were assumed to be eighty percent of the current Saturn V costs. (The main stage must absorb the major portion of the computer costs.) Ten percent of the costs were attributed to the engine module of the injection stage. Two and one-half percent of the costs were attributed to each fuel module of the injection stage. Five percent of the costs were attributed to the SRM stages.

AMLLV configuration element test costs were determined by multiplying the MLLV configuration element test costs by 110 percent.

These costs, as discussed above, are rough estimates. The incorporation of onboard test and checkout capability in the vehicle design further adds to the grossness of these estimates. The costs as shown are believed to be well on the conservative side.

The costs shown represent total program costs for accomplishment of the breadboard tests.

TABLE 4.2.5.2-I BREADBOARD TEST COSTS

	AMLLV	MLLV
Main (Core) Stage	$ 80,520,000	$ 73,200,000
Additional Costs Attributable to Injection Stage Engine Module	$7,937,000	$7,215,000
Additional Costs Attributable to Injection Stage Fuel Module	$2,519,000	$2,288,000
Additional Costs Attributable to SRM Stages	$ 5,033,000	$ 4,575,000
Totals (With 2 Fuel Modules)	$98,528,000	$89,566,000

4.2.6 Structural (Static) Tests

The objective of structural tests will be to determine the ability of the stage structures to withstand predicted static and dynamic forces which may be encountered in assembly, storage, transportation, handling, testing, and flight.

Structural tests will be performed on the largest practicable assemblies of structural hardware for all stages and modules. As a prerequisite, tests of structural details and component structures will have been completed and evaluated.

The following will be considered in the development of detailed structural test plans:

a. The determination of effects of aerodynamics, cryogenics, winds, thrust, vibration, and static forces, etc.;

b. The determination of effects of multiple environments on the structure;

c. The determination of safety factors, failure characteristics, and design limitations by the proper sequencing and application of overstress;

d. The completion of portions of the structural tests that are related to specific events prior to the performance of the events such as transportation, static test firing, etc.

4.2.6.1 Test Description

Static load test conditions that were considered probable are listed below. This list should not be construed as a complete list of test conditions required.

a. Main Stage Tank Assembly:

1. "Pneumastatic" Proof Pressure,
2. Cryogenic (LN_2 - LH_2) to Maximum Operating Pressures,
3. Maximum Combined Axial Loads at Cryogenic Operating Pressures,
4. LOX Tunnel and LH_2 Fitting Loads at Cryogenic Operating Pressures,
5. Lower Bulkhead Inertial Loads with Ambient Water and/or Gas Operating Pressures;

b. Main Stage Thrust Structure - Combined Axial and Lateral Loads at:

1. Full Core Stage Thrust, 0^{o} Thrust Deflection - Ambient,
2. Full Core Stage Thrust, Full Thrust Deflection - Ambient,
3. Full Core Stage Thrust with Lateral Strap-on Loads,
4. Same as No. 1 above with Thermal Simulation,
5. Same as No. 2 above with Thermal Simulation,
6. Same as No. 3 above with Thermal Simulation;

4.2.6.1 (Continued)

c. Main Stage Upper Skirt - Combined Axial and Lateral Loads at:

1. Full Core Stage Thrust with Holddown,
2. Full Core Stage Thrust,
3. Full Strap-On Thrust with Holddown,
4. Full Strap-On Thrust,
5. Strap-On Thrust with Critical Strap-On(s) Out;

d. Injection Stage Assembly - Combined Axial and Lateral Loads at:

1. Full Injection Stage Thrust (0^{o} Thrust Deflection),
2. Full Injection Stage Thrust (Max. Thrust Deflection),
3. Full Core Stage Thrust (0^{o} Thrust Deflection),
4. Full Core Stage Thrust (Max. Thrust Deflection),
5. Full Strap-On Thrust,
6. Strap-On Thrust with Critical Strap-On(s) Out;

e. Injection Stage LH_2 and LOX Tanks:

1. Pneumastatic Proof Pressure,
2. Cryogenic to Operating Pressure;

f. SRM Stage Attach Hardware:

1. Combined Maximum Axial and Lateral Loads to be Experienced During Flight,
2. Combined Loads Simulating Load Conditions at Various Flight Times,
3. Support Loads in the Prelaunch Position.

g. Solid Rocket Motor Case:

1. Hydrostatic Proof Pressure,
2. Hydrostatic Proof Pressure Combined with Maximum Axial and Lateral Loads,
3. Support Loads in the Prelaunch Position.

4.2.6.2 Resource Requirements

New facilities must be provided for conducting the static load testing for the liquid stage and the SRM stage hardware. Load tests of the liquid stage hardware and initial tests of the SRM attach hardware will be accomplished at a new test facility adjacent to the Michoud manufacturing facility. Hydrostatic testing combined with axial and lateral load testing of the SRM case and assembled attach hardware will be conducted at the SRM manufacturing facility.

4.2.6.2 (Continued)

The new facilities at the Michoud site are discussed below.

Static Load Test Facility (Ambient) — This facility will provide the capability of reacting maximum simulated flight loads on either the thrust structure, upper skirt, or the injection stage or SRM attach structure (where applicable). Multiple floor tie-down capability and a movable upper reaction head will be necessary to accommodate the different heights and loading conditions required for the above mentioned specimens.

Remote Static Load Test Facility (Cryogenic) — This facility will provide the capability of reacting maximum simulated flight loads on the stage assembly under either cryogenic (LH_2, LN_2) or ambient conditions. LH_2 Supply and disposal systems, water fill and pressurization systems, gas pressurization systems, and the high density fluid system will be located adjacent to the facility.

The major test specimens required for the various configuration elements were defined as follows:

a. Single Stage-to-Orbit (Main Stage):

1. LOX-LH_2 core stage tank assembly with attached lower thrust structure, base plug assembly and upper skirt,
2. Separate lower thrust structure with plug and gimbal attachment fittings,
3. Separate upper skirt (light weight);

b. Injection Stage (Engine Module):

1. One set (LH_2 and LOX) tanks,
2. One skin structure;

c. Injection Stage (Fuel Module):

1. One set (LH_2 and LOX) tanks,
2. One skin structure;

d. SRM Stage (Testing at Michoud Facility):

1. One set of attach structures,
2. One main stage heavy weight forward skirt;

e. SRM Stage (Testing at Aerojet):

1. Three sets of attach structures,
2. One SRM case.

4.2.6.2 (Continued)

e. (Continued)

NOTE: As these tests at Aerojet will be conducted as part of the SRM development and PFRT test program, they are not discussed further in this section (see Section 4.2.9).

The above specimens must be structurally complete. They will not include such items, however, as electrical or hydraulic components. The costs of these specimens to support this test program were defined as equivalent to the first unit costs of operational hardware. An additional charge of 10 percent was attributed to these specimens to cover load testing at the subcomponent level.

Tables 4.2.6.2-I through -VIII itemize the AMLLV and MLLV resource requirements attributable to 1) the single stage-to-orbit vehicle, 2) the additional resource requirements attributable to static load test of the injection stage (engine module and fuel modules), and 3) additional resource requirements attributable to the SRM stage. Each table also shows the resulting total program cost (after using costing factors) attributable to the static load test for the main stage, and the additional costs attributable to the addition of 1) an injection stage, engine module, 2) injection stage, fuel modules, and 3) SRM solid rocket-motor stages.

Table 4.2.6.2-I. STATIC LOAD TEST - AMLLV MAIN STAGE

	TANK ASSEMBLY	THRUST STRUCTURE	FORWARD SKIRT	COMPONENTS	TOTAL
ENGR. MANHOURS (DIRECT)	124,709	83,094	41,629	50,610	300,042
MFG. MANHOURS (DIRECT)	256,128	179,258	85,345	95,986	616,717
TEST MATERIALS	$ 657,000	$ 418,000	$ 91,000	$ 157,000	$ 1,323,000
TOOLING		INCLUDED IN THE ABOVE MANHOURS AND MATERIAL			
TEST SPECIMEN	$34,383,000	$4,647,000	$3,637,000	$4,267,000	$46,934,000
FACILITY AND EQUIPMENT					$24,174,000
FACILITY MAINTENANCE					$ 1,082,000

TOTAL COST = $86,067,000 (INCLUDES PRICING FACTORS)

Table 4.2.6.2-II. STATIC LOAD TEST - AMLLV INJECTION STAGE ENGINE MODULE

	TANK ASSEMBLY	STAGE ASSEMBLY	COMPONENTS	TOTAL
ENGR. MANHOURS	11,319	38,170	15,776	65,265
MFG. MANHOURS	22,656	75,925	31,441	130,022
TEST MATERIALS	$ 27,000	$ 76,000	$ 33,000	$ 136,000
TOOLING	INCLUDED IN ABOVE MANPOWER AND MATERIAL ESTIMATES			
TEST SPECIMEN	$4,616,000	$6,457,000	$1,107,000	$12,180,000
FACILITY AND EQUIPMENT	SHARES MAIN STAGE TEST FACILITY			
FACILITY MAINTENANCE				

TOTAL COST = $15,023,000 (INCLUDES PRICING FACTORS)

Table 4.2.6.2-III. STATIC LOAD TEST - ADDITIONAL REQUIREMENTS FOR AMLLV INJECTION STAGE FUEL MODULE

	TANK ASSEMBLY	STAGE ASSEMBLY	COMPONENTS	TOTAL
ENGR. MANHOURS	1,256	6,237	INCLUDED IN ENGINE MODULE	7,493
MFG. MANHOURS	3,542	8,352	INCLUDED IN ENGINE MODULE	11,894
TEST MATERIALS	$ 7,000	$ 1,000	INCLUDED IN ENGINE MODULE	$ 8,000
TOOLING	INCLUDED IN ABOVE MANPOWER AND MATERIAL ESTIMATES			
TEST SPECIMEN	$3,907,000	$3,093,000	$700,000	$7,490,000
FACILITY AND EQUIPMENT	SHARES MAIN STAGE TEST FACILITY			
FACILITY MAINTENANCE	SHARES MAIN STAGE TEST FACILITY			

TOTAL COST = $7,992,000 (INCLUDES PRICING FACTORS) (ADDITIVE TO INJECTION STAGE ENGINE MODULE COSTS)

Table 4.2.6.2-IV. STATIC LOAD TEST - AMLLV SRM STAGE

	ATTACH STRUCTURE	DELTA COST FOR HEAVY WEIGHT MAIN STAGE FORWARD SKIRT AND COMPONENTS	SRM CASE AND NOZZLE
ENGR. MANHOURS	1,480	27,579	INCLUDED
MFG. MANHOURS	18,284	37,806	IN
TEST MATERIALS	$ 36,000	$ 70,000	SRM
TOOLING	INCLUDED IN ABOVE	INCLUDED IN ABOVE	DEVELOPMENT
TEST SPECIMEN	$1,725,000	$4,630,000	COSTS
FACILITY AND EQUIPMENT			SEE
	NO CHANGE	NO CHANGE	SECTION
FACILITY MAINTENANCE			4.2.9

TOTAL COST = $7,695,000 (INCLUDES PRICING FACTORS)

Table 4.2.6.2-V. STATIC LOAD TEST - MLLV MAIN STAGE

	STAGE ASSEMBLY	THRUST STRUCTURE	FORWARD SKIRT	COMPONENTS	TOTAL
ENGR. MANHOURS	123,352	82,573	41,387	47,078	294,390
MFG. MANHOURS	233,020	156,229	78,114	89,031	556,394
TEST MATERIALS	$ 619,000	$ 414,000	$ 84,000	$ 96,000	$1,213,000
TOOLING		INCLUDED IN THE ABOVE MANHOURS AND MATERIAL			
TEST SPECIMEN	$23,464,000	$3,162,000	$2,353,000	$2,897,000	$31,876,000
FACILITY AND EQUIPMENT					$20,444,000
FACILITY MAINTENANCE					$ 1,008,000

TOTAL COST = $66,420,000 (INCLUDES PRICING FACTORS)

Table 4.2.6.2-VI. STATIC LOAD TEST - MLLV INJECTION STAGE ENGINE MODULE

	TANK ASSEMBLY	SKIN ASSEMBLY	COMPONENTS	TOTAL
ENGR. MANHOURS	10,725	35,944	14,121	60,790
MFG. MANHOURS	20,250	68,136	26,710	115,096
TEST MATERIALS	$ 23,000	$ 74,000	$ 29,000	$ 126,000
TOOLING	INCLUDED IN ABOVE MANPOWER AND MATERIAL ESTIMATES			
TEST SPECIMEN	$3,132,000	$4,745,000	$788,000	$8,665,000
FACILITY AND EQUIPMENT	SHARES MAIN STAGE TEST FACILITY			
FACILITY MAINTENANCE				

TOTAL COST = $11,206,000 (INCLUDES PRICING FACTORS)

Table 4.2.6.2-VII. STATIC LOAD TEST - MLLV INJECTION STAGE FUEL MODULE

	TANK ASSEMBLY	STAGE ASSEMBLY	COMPONENTS	TOTAL
ENGR. MANHOURS	1,192	3,139	INCLUDED IN ENGINE MODULE	4,331
MFG. MANHOURS	2,242	5,675		9,899
TEST MATERIALS	$ 3,000	0		$ 2,000
TOOLING	INCLUDED IN ABOVE MANPOWER AND MATERIAL ESTIMATES			
TEST SPECIMEN	$2,429,000	$2,189,000	$462,000	$4,899,000
FACILITY AND EQUIPMENT	SHARES MAIN STAGE TEST FACILITY			
FACILITY MAINTENANCE				

TOTAL COST = $4,295,000 (INCLUDES PRICING FACTORS) (ADDITIVE TO INJECTION STAGE ENGINE MODULE COSTS)

Table 4.2.6.2-VIII. STATIC LOAD TEST - MLLV SRM STAGE

	NOSE CONE AND ATTACH STRUCTURE	DELTA COSTS FOR HEAVY WEIGHT MAIN STAGE FORWARD SKIRT	SRM CASE AND NOZZLE
ENGR. MANHOURS		23,116	INCLUDED
MFG. MANHOURS	1,748	44,873	IN
TEST MATERIALS	$ 1,598	$ 56,000	SRM
TOOLING	$ 191,000	INCLUDED IN ABOVE	DEVELOPMENT
TEST SPECIMEN	$ 590,000	$ 2,950,000	COSTS.
FACILITY AND EQUIPMENT			SEE
	$ 263,000	NO CHANGE	SECTION
FACILITY MAINTENANCE			4.2.9

TOTAL COST = $4,840,000 (INCLUDES PRICING FACTORS)

4.2.7 Dynamic Tests

Dynamic tests will be conducted to determine the structural and vibrational characteristics of the launch vehicle, including payload, under dynamically simulated flight load conditions.

The objectives of dynamic tests will be to:

a. Determine the structural dynamic characteristics under conditions simulating flight dynamics insofar as practicable;

b. Qualify the hardware to perform within the characteristics determined above;

c. Determine physical mating compatibility of stages and modules;

d. Compare dynamic test results with subsequent flight test results for continuous development of dynamic test techniques and facilities, to assure the highest possible degree of accuracy in the development and qualification of the vehicle structure prior to flight.

4.2.7.1 Test Description

To conduct these tests, structurally complete liquid stages will be provided. These stages will not include electrical or hydraulic components. Engines and subsystems will be simulated with appropriately mounted lump masses. SRM stages will not be provided for these tests. The effects of the SRM stages, where applicable, will be simulated by providing a programmed input to hydrodynamic shakers attached to the dynamic vehicle at the SRM stage attach points.

Dynamic tests will be conducted on each of the various configurations that will make up the vehicle family in its operational status.

The dynamic test vehicle will be assembled to the same configuration as for the flight mode. The appropriate test specimens will be assembled to make up the desired configurations. As these tests are nondestructive, test specimens will not be duplicated. The hardware provided for the dynamic test vehicle will not subsequently be used for flight hardware.

4.2.7.2 Resource Requirements

The size of the dynamic test facility required is beyond the capabilities of the Saturn V facilities. Therefore, a complete new stand will be required for either the half size MLLV or full size AMLLV configuration. The solid motor weights will not be duplicated for the dynamic tests, but their load effects on the core vehicle will be simulated. The location of the new dynamic test facility will be adjacent to navigable water at the manufacturing site.

4.2.7.2 (Continued)

The following is a summary of the type of anticipated equipment and brick and mortar items costed:

a. Foundations and earth work;
b. Super structure,
c. Architectural finishing,
d. Mechanical systems,
e. Electrical systems.

The costs were established based on the full size AMLLV vehicle. The costs for MLLV facilities as shown, were based on the facilities size reduction and facilities engineering judgment.

The cost dollar figures given for the facilities include the following phases and resources of project accomplishment.

Accomplishment Phase	Resource
Concepts and planning	Aerospace company
Design criteria	A&E contractor
Final design and specifications	A&E contractor
Construction	General construction contractor
Construction surveillance	A&E contractor and aerospace company
Contract administration	Aerospace company

The test equipment costs, as tabulated on the cost summaries, include the required test equipment, facility type purchasable equipment, and all ground support equipment except stage handling tools or fittings.

The dynamic test facility and equipment requirements will not be significantly affected by the addition of the injection stage engine or fuel modules as the vehicle diameter will remain constant, and the overall vehicle weight and height will increase only slightly.

4.2.7.2 (Continued)

The equipment and facility requirements will, however, be substantially increased if SRM stages are simulated. Larger hydrodynamic shakers will be required. The foundations must be increased to account for the higher loads to be applied. The dynamic test facility for this application will be a silo rather than an above ground structure. If the structure were above ground, high, vertical pylons (concrete) would have to be provided to mount the shakers for input of loads to the forward skirt of the main stage.

Equipment costs cover:

a. Estimated delivered cost,
b. Equipment installation,
c. Equipment engineering support.

The major test specimens required for the various configuration elements were defined as follows:

a. Single-stage-to-orbit vehicle

   1. One main stage assembly with lump mass simulators,
   2. Simulated payload with IU;

b. Additional specimens required for injection stage engine module

   1. One injection stage assembly with lump mass simulators,
   2. Larger simulated payload section with IU;

c. Additional specimens required for each injection stage fuel module - One fuel module assembly with lump mass simulators;

d. Additional requirements for SRM stage

   1. Enlarged simulated payload section with IU,
   2. One heavy weight main stage forward skirt.

The specimens will be structurally complete, but will not include such items as electrical or hydraulic components. Weights, attachments and center of gravity locations will be simulated. The cost of the above specimens was determined by using the first unit production costs of similar specimens (structural components) for the first flight vehicle. Twenty percent was added to these costs to account for the cost of the lump mass simulators and the costs of the simulated payload and IU.

4.2.7.2 (Continued)

The "F" vehicle will be used to check out the dynamic test facility. As the dynamic facility checkout would not be required without the requirement for a dynamic test program, this operation is charged against the dynamic test costs. The "F" vehicle hardware will be available from other operations to perform this checkout, and therefore was not charged against the dynamic test program costs.

Summaries of the overall resource requirements for dynamic test of the AMLLV and MLLV single-stage-to-orbit vehicles (as provided for costing) are shown in Table 4.2.7.2-I. This chart shows the total resource requirements for providing the facility, the facility checkout, the test specimen, and for conducting the dynamic tests. The inputs as shown were subjected to costing factors to define the total program costs associated with dynamic tests as shown at the bottom of Table 4.2.7.2-I. Tables 4.2.7.2-II through 4.2.7.2-IV show the additional resource requirements and costs attributable to the injection stage engine module, injection stage fuel module and SRM simulation respectively.

TABLE 4.2.7.2-1 DYNAMIC TEST - AMLLV AND MLLV SINGLE STAGE TO ORBIT VEHICLE

	AMLLV	MLLV
ENGR. MANHOURS (DIRECT FOR TEST)	312,314	296,961
MFG. MANHOURS (DIRECT FOR TEST)	549,508	504,086
TEST MATERIALS	$1,477,000	$1,391,000
TOOLING	INCLUDED IN ABOVE M/HOURS & MATERIAL	
TEST SPECIMEN	$34,383,000	$23,464,000
FACILITY	$7,455,000	$6,320,000
TEST EQUIP.	$6,000,000	$6,000,000
INSTRUMENTATION EQUIP.	$3,300,000	$3,300,000
FAC. & EQUIP. CHECKOUT, "F" VEH.	INCLUDED IN ABOVE TEST MANHOURS AND MATERIAL	
FAC. & EQUIP. MAINTENANCE (9 MOS.)	$382,000	$325,000
TOTAL PROGRAM COST (INCLUDES PRICING FACTORS)	$66,057,000	$53,104,000

TABLE 4.2.7.2-II ADDITIONAL DYNAMIC TEST REQUIREMENTS FOR INJECTION STAGE ENGINE MODULE

	AMLLV	MLLV
ENGR. MANHOURS (DIRECT FOR TEST)	77,929	70,520
MFG. MANHOURS (DIRECT FOR TEST)	151,807	119,745
TEST MATERIALS	$373,000	$340,000
TOOLING	INCLUDED IN ABOVE M/HRS. & MATERIAL	
TEST SPECIMEN	$11,073,000	$7,881,000
FACILITY	$1,000,000	$850,000
TEST EQUIP.	NO CHANGE	NO CHANGE
INSTRUMENTATION EQUIP.	NO CHANGE	NO CHANGE
FAC. & EQUIP. CHECKOUT, "F" VEH.	INCLUDED IN ABOVE TEST MANHOURS AND MATERIAL	
FAC. & EQUIP. MAINTENANCE	NO CHANGE	NO CHANGE
TOTAL ADDITIONAL PROGRAM (INCLUDES PRICING FACTORS)	$15,738,000	$12,000,000

TABLE 4.2.7.2-III ADDITIONAL DYNAMIC TEST REQUIREMENT FOR ADDING INJECTION STAGE FUEL MODULE TO INJECTION STAGE ENGINE MODULE

	AMLLV	MLLV
ENGR. MANHOURS (DIRECT FOR TEST)	NO INCREASE OVER ENGINE MODULE REQUIREMENTS	
MFG. MANHOURS (DIRECT FOR TEST)		
TEST MATERIALS		
TOOLING		
TEST SPECIMEN	$9,306,000	$6,706,000
FACILITY	$ 500,000	$ 425,000
TEST EQUIP.	NO CHANGE	NO CHANGE
INSTRUMENTATION EQUIP.	NO CHANGE	NO CHANGE
FAC. & EQUIP. CHECKOUT, "F" VEH.	INCLUDED IN ABOVE TEST MATERIAL AND MANHOURS	
FAC. & EQUIP. MAINTENANCE	NO CHANGE	NO CHANGE
TOTAL ADDITIONAL PROGRAM COST (INCLUDES PRICING FACTORS)	$9,806,000	$7,131,000

TABLE 4.2.7.2-IV ADDITIONAL DYNAMIC TEST REQUIREMENTS FOR SRM SIMULATION

	AMLLV	MLLV
ENGR. MANHOURS (DIRECT FOR TEST)	19,234	17,900
MFG. MANHOURS (DIRECT FOR TEST)	40,392	29,916
TEST MATERIALS	93,000	85,000
TOOLING	MAN HOURS INCLUDED IN ABOVE AND MATERIALS	
TEST SPECIMEN	$5,629,000	$3,910,000
FACILITY	$7,000,000	$5,250,000
TEST EQUIP.	$10,000,000	$7,500,000
INSTRUMENTATION EQUIP.	NO CHANGE	NO CHANGE
FAC. & EQUIP. CHECKOUT, "F" VEH.	INCLUDED IN ABOVE TEST MANHOURS AND MATERIAL	
FAC. & EQUIP. MAINTENANCE	NO CHANGE	NO CHANGE
TOTAL ADDITIONAL PROGRAM COST (INCLUDES PRICING FACTORS)	$24,104,000	$18,508,000

4.2.8 Main and Injection Stage Engine Development and Qualification Tests

This section describes the development and qualification program of the liquid engine systems for both the main and the injection stages of the AMLLV/MLLV vehicles. The magnitude of the main stage engine program will be dependent upon the type of engine system used (i.e., the multichamber/plug or the toroidal/aerospike). The baseline system discussed in this section and subsequently used for costing of the baseline program is the Pratt and Whitney multichamber/plug engine system. The Pratt and Whitney high pressure bell engine module can be used both for the main stage and for the injection stage propulsion. The following test plan (Paragraph 4.2.8.1), therefore, is applicable to the engine modules for both of these stages. Paragraph 4.2.8.2 describes the individual resource requirements for the main stage engine system and for the engine modules for the injection stage respectively. A development and qualification program for the main stage toroidal/aerospike engine system was provided by Rocketdyne and is discussed in Section 9.0, Resource Requirements for Design Alternatives.

4.2.8.1 Test Description

The following preliminary program plan was provided by Pratt and Whitney. It is based on the development of a high performance, staged combustion, bell nozzle, oxygen-hydrogen rocket-engine module rated at a vacuum thrust level within the 100,000-500,000 lb. range and having variable thrust and mixture ratio capability. The completion of Preliminary Flight Rating Test (PFRT) will be 42 months after start of the program and completion of an engine Model Qualification Test (MQT) 15 months thereafter. The extent of work necessary to develop the engine module was based on experience in the RL-10 program, during which 640 engine system tests were conducted over a 36-month period from the initiation of design to PFRT.

Component testing will be accomplished prior to incorporating these items into the engine assembly. Tests of the flight fuel and oxidizer turbopumps, preburner, main combustion chamber, two-position nozzle, low-speed inducers, and control system components will be conducted as early in the program as additional facility and hardware procurement will permit. Continuing component testing throughout the development period is planned to establish and develop component performance and to determine operational limits of the components within the limitations of the engine environment. These tests are planned to supplement the main effort of flight engine system development testing.

The engine module program will consist of development testing to achieve the system operating characteristics, performance, maintainability, versatility and reliability commensurate with manned vehicle requirements and to fully explore and resolve the vehicle/engine interface problems. All engine test stands are designed to permit full-duration firings of at least 600 seconds. A high percentage of the firings will be conducted for this duration. Eight experimental engines will be active at the time of the PFRT. Approximately 700 full-scale engine firings will be conducted prior to the PFRT. An additional 1300 firings, including tests under simulated operational attitude conditions, will be conducted in the period between the PFRT and the completion of the

MQT. Included in these firings will be engine-to-vehicle integration tests that will be conducted on a test stand designed to simulate the vehicle interfaces. The major program milestones and the overall engine module program schedule are shown in Figure 4.2.8.1-1.

An engine module as defined in the preceding and following discussions relates to the individual high pressure bell engine assembly which includes a one twenty-fourth section of the regeneratively cooled plug plus a gas generator to provide pressurization gas for the base plug. Twenty-four of these individual modules will be assembled around the base of the plug to comprise the total engine system. The engine module for the injection stage is the complete engine. (The number of complete engines varies from two to six depending upon the injection stage configuration.)

No major new engine test facilities will be required, as the engine systems will be tested by individual module. The first complete test of the assembled main stage engine system will occur at the first static firing of the main stage as discussed in a subsequent section.

Component Development

The development program for the major components will include extensive performance and reliability testing at simulated service conditions. The tests of the fuel turbopump, oxidizer turbopump, preburner and main combustion chamber injectors, combustion chamber assembly, and control system elements will be conducted to assure the required reliability and performance of these components prior to incorporation into the PFRT engine configuration. Tests of the fuel and oxidizer turbopump assemblies will be conducted to develop satisfactory operation over the full operating range, with particular attention to the starting and transient performance. The combustion and ignition systems will be tested to ensure safe, reliable, and repeatable performance compatible with engine requirements. Similarly, the propellant control and shutoff valves must be developed to the point where required performance and reliability characteristics have been demonstrated. Concurrent with the engine test program, the component programs will be continued to reflect new component design requirements as dictated by the results of the engine development program.

Within the overall program, testing of the preburner assembly is scheduled to establish satisfactory ignition and combustion prior to incorporating in the flight engine test program. Ignition tests are planned to provide the starting propellant flow rates. These tests will establish the preburner starting envelope in terms of mixture ratio, chamber pressure, and the required propellant flow rates.

Subsequent tests are planned to evaluate performance, endurance, and the response rates of the preburner system at operating pressures and temperatures. The important preburner development milestones, development schedule and parts requirements are shown in Figure 4.2.8.1-2.

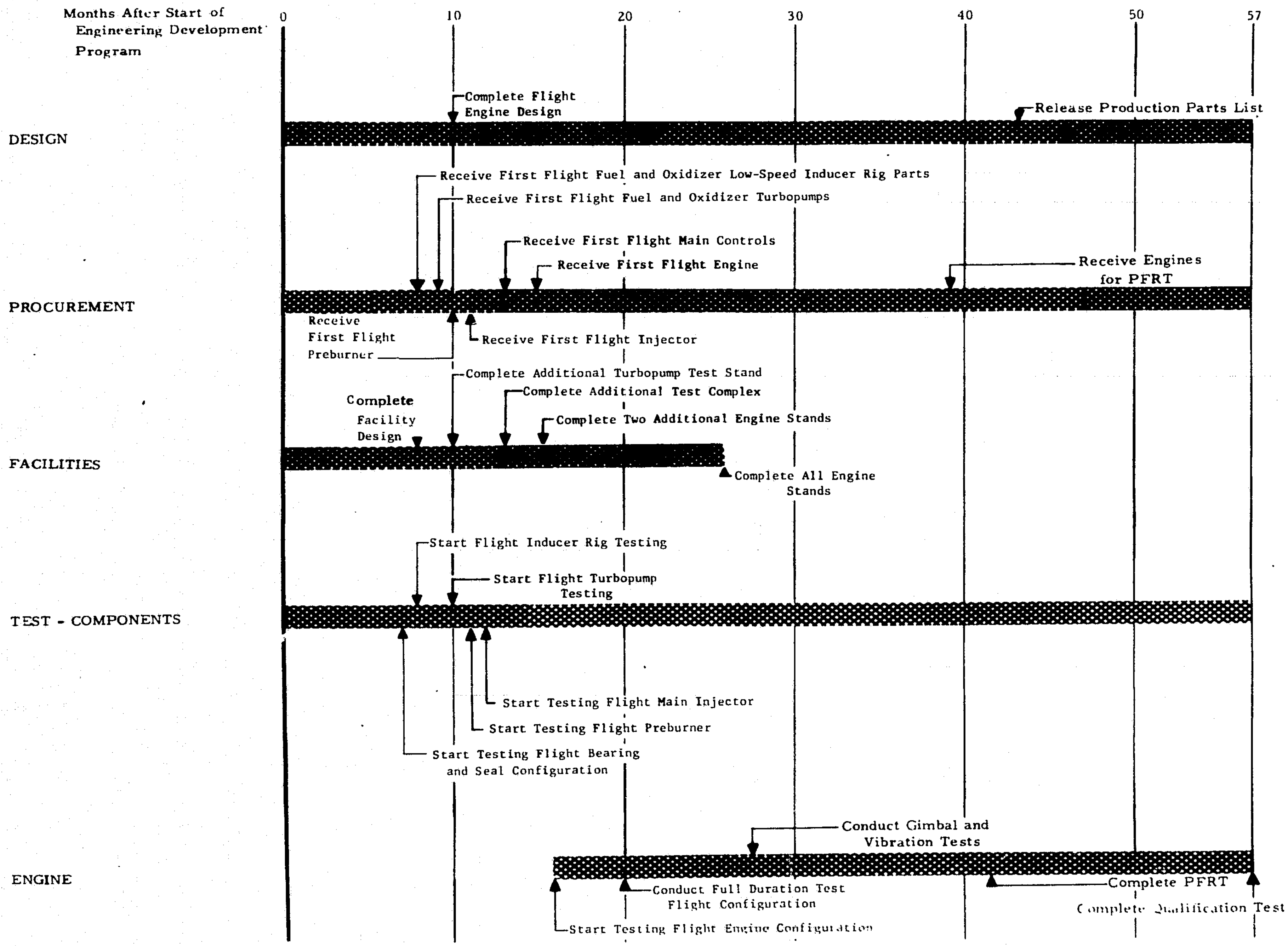


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FIGURE 4.2.8.1-1 OVERALL PROGRAM SCHEDULE

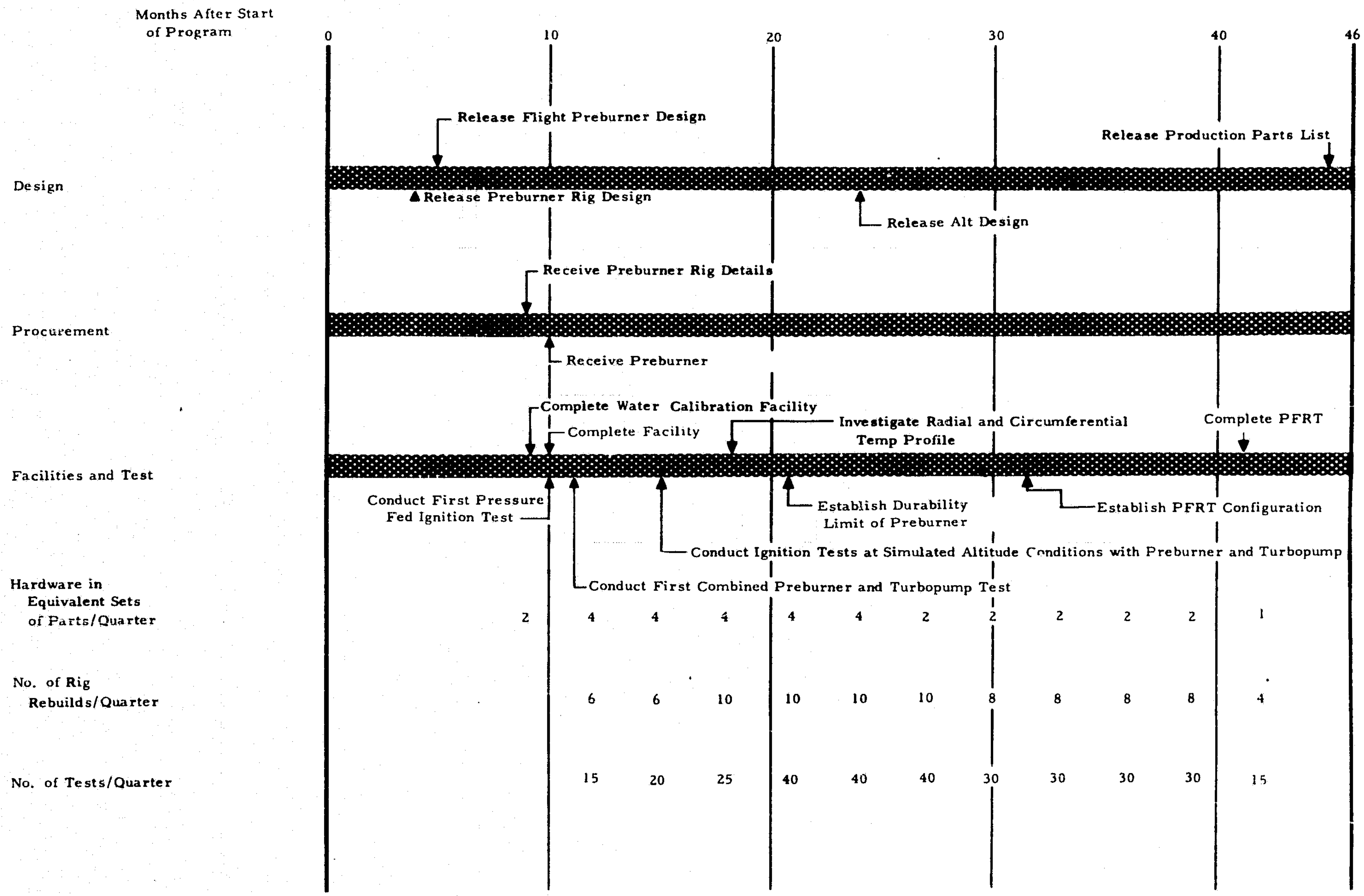

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FIGURE 4.2.8.1-2 PREBURNER DEVELOPMENT PROGRAM

4.2.8.1 (Continued)

Utilizing modified flight components, the ignition, start transient, and steady-state operating conditions will be investigated. The ignition tests will establish the propellant starting flows and valve sequencing. The steady-state and transient tests will subject the preburner to the pressures, temperatures, and stress levels simulating engine operation. The transient testing will also provide an assessment of the control scheduling required to achieve the desired acceleration and deceleration transients.

Tests to establish the preburner temperature profile are required to assure uniform radial and circumferential temperature distributions consistent with turbine durability and performance requirements. Preburner tests will be made over the full range of engine operation to investigate and establish the combustion stability margin of the configuration using a pulse gun to trigger a pressure wave during preburner operation. The effects of inlet pressure, inlet temperature, and mixture ratio on combustion performance will be established through repeated tests.

Main injector and combustion chamber tests will be conducted by utilizing both pressurized facilities and the flight engine high-pressure fuel and oxidizer turbopumps, modified controls, and the preburner to supply the high-pressure propellants to the main chamber assembly. The important milestones of the main combustion chamber and injector program plus the parts requirements are shown in Figure 4.2.8.1-3.

Nonfiring tests of the main injector utilizing water on the oxidizer side and gaseous nitrogen on the fuel side will be conducted to evaluate atomization and distribution of the injector configuration. High-speed photography and spray pattern measuring equipment will be used to evaluate both circumferential and radial flow distribution prior to actual combustion tests. Internal propellant flow passage pressure losses will be measured. Hot firing tests of the injector with heavy duty, uncooled thrust chambers are planned to evaluate the stability and efficiency of the injector, to confirm injector element spacing and propellant mixing characteristics. The tests to evaluate combustion system performance will be conducted on both pressurized facilities and the flight engine. The susceptibility of the injector and thrust chamber assembly to combustion instability will be evaluated by pulsing the chamber and measuring the time required for the pressure to decay. The effect of variations of propellant inlet temperatures, inlet pressure, and mixture ratio on combustion performance will be included in the test series. Evaluation of alternative injector designs, incorporating varying numbers of point sources and different orifice configurations, is also planned. Long-duration engine tests are scheduled to obtain an endurance evaluation of the injector mixture ratio profile on chamber durability.

The testing of the cooled combustion chamber will be integrated with development engine testing. These tests will utilize the regeneratively cooled nozzle assembly to obtain proper coolant inlet temperature and pressures to the transpiration cooled combustion chamber. The major objectives of this test program are performance and the optimization of the cooling flow requirements to be consistent with the engine durability and life requirements. The program will also include the evaluation of

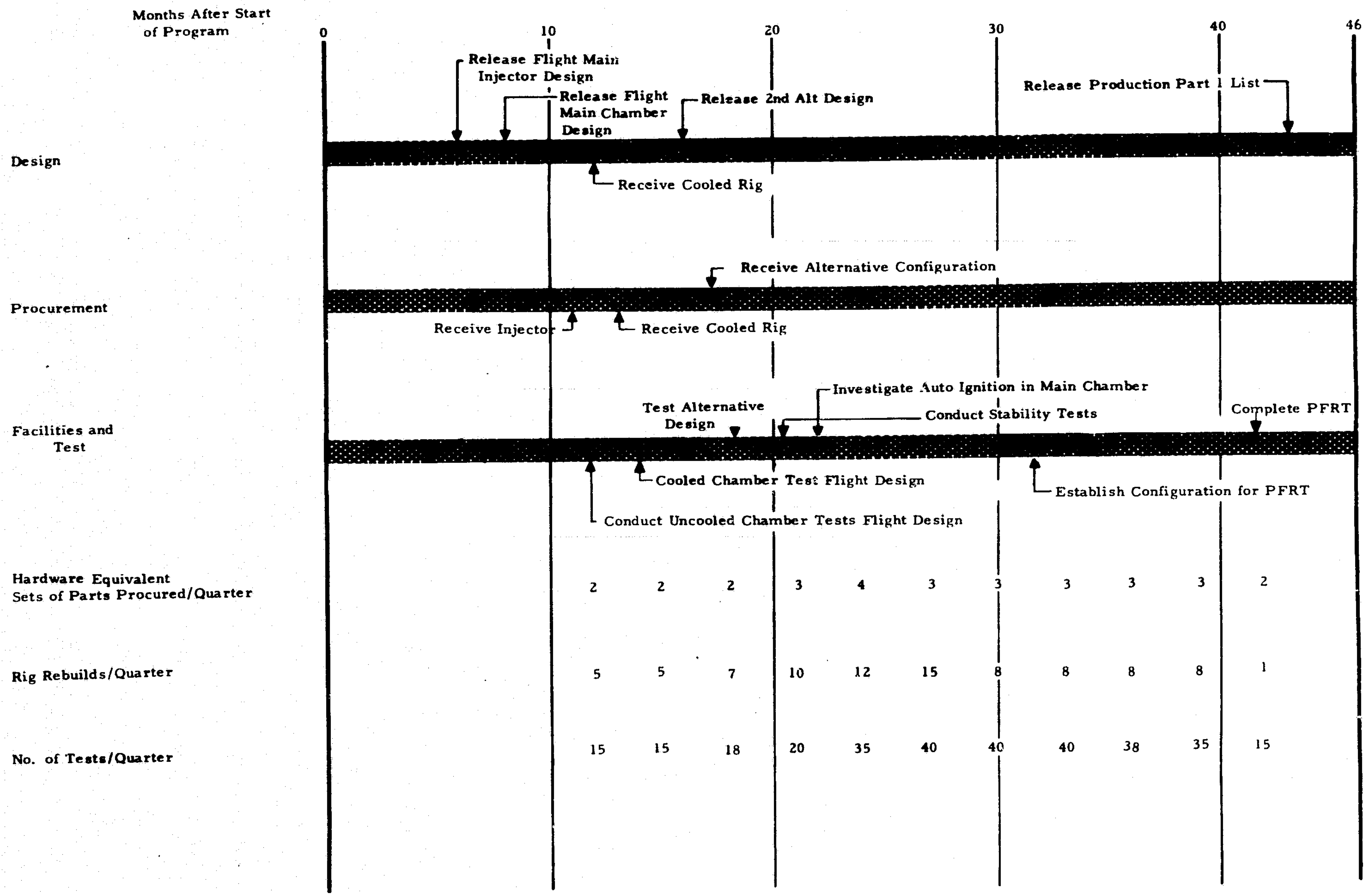

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FIGURE 4.2.8.1-3 MAIN COMBUSTION CHAMBER AND INJECTOR DEVELOPMENT PROGRAM

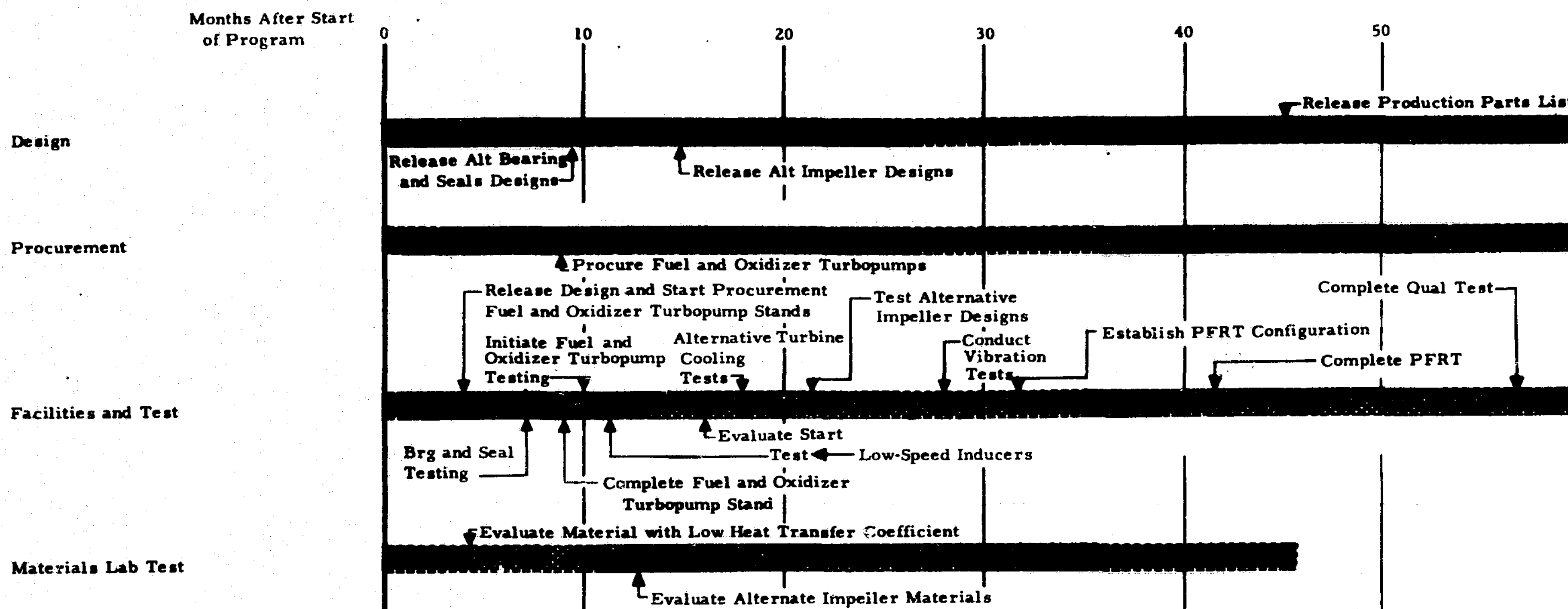
4.2.8.1 (Continued)

component performance and durability testing over the full operating range of mixture ratios and chamber pressures. An automatic data recording system will be utilized to measure combustion chamber and propellant pressures, coolant temperatures, and propellant flow rates to permit calculation of combustion and heat transfer characteristics in the cooled combustion chamber and regeneratively cooled nozzle section. Instrumentation will be incorporated in the transpiration cooled wall to measure the metal temperatures to assess adequacy of the design and establish the operating margin. An investigation into potential combustion instability of the injector when operating with the transpiration cooled thrust chamber is also included. Forced pressure oscillations will be established with a pulse gun, and rate of decay of the forced oscillation will be recorded. Nonfiring tests to demonstrate structural integrity of the thrust chamber assembly will be included. These tests will subject the chamber assembly to vibration and pressure loading, simulating normal and abnormal engine operating conditions.

The turbopump program will include testing to further develop the required performance of the various subcomponents (such as bearings, seals, and thrust balance systems) as well as extensive performance and endurance testing of the complete turbopump assemblies under simulated engine operating conditions. The major milestones of the turbopump development with hardware requirements are shown in Figure 4.2.8.1-4.

The objective of the fuel turbopump program will be to obtain performance, durability, and reliability commensurate with engine requirements. Extensive testing is planned with the complete turbopump assembly as well as with subcomponents such as bearing and thrust balance rigs. Turbine power will be obtained from heat exchangers as shown in the schematic of the test facility in Figure 4.2.8.1-5. Propellant supply lines, which simulate the propellant inlet ducts of the vehicle, will be included in the facilities to evaluate vehicle system interactions on the engine system and particularly the low-speed inducers and main turbopumps. The program will include testing of the fuel low-speed inducer in conjunction with the fuel turbopump. The turbopump assemblies will be instrumented to measure propellant flow rates, pressures, temperatures, rotational speeds, and vibration. Starting tests will be included to establish the propellant inlet conditions required to achieve transient turbopump performance consistent with engine requirements. Provision for alternative designs of inducers, impellers, and turbine cooling configurations, as well as alternative materials, will be included in the program to determine their effect on performance and durability. The planned subcomponent and complete turbopump assembly testing will permit the determination and development of the transient performance of the turbopump under simulated engine operating conditions, as well as provide endurance testing of the bearings and thrust balance system prior to engine testing.

The primary objectives of the oxidizer turbopump development program will be to establish the performance, durability, and reliability commensurate with engine requirements. This testing is planned with subcomponent seal, bearing and thrust balance rigs, as well as with complete turbopump assemblies. Additional tests will



Hardware (Equiv Sets Parts per Quarter)	Fuel Turbopump	1	2	3	3	2	1	1	1	1	1	1	1	1	1	1	1	1	
	Oxidizer Turbopump	1	2	3	3	2	2	1	1	1	1	1	1	1	1	1	1	1	
Rig Tests (Per Quarter)	Bearing and Thrust Balance (Fuel/Oxidizer)	6/4	6/4	6/4	6/4	6/4	6/4	3/2	3/2	3/2	3/2	3/2	3/2	3/2	3/2	3/2	3/2	3/2	2/3
	Seal	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	5	3
	Full-Scale Fuel Turbopump		6	8	16	16	16	16	16	16	16	16	16	16	16	16	16	16	12
	Full-Scale Oxidizer Turbopump		6	8	16	16	16	16	16	16	16	16	16	16	16	16	16	16	12
Rig Rebuilds (Per Quarter)	Bearing and Thrust Balance (Fuel/Oxidizer)	6/4	6/4	6/4	6/4	6/4	6/4	3/2	3/2	3/2	3/2	3/2	3/2	3/2	3/2	3/2	3/2	3/2	2/3
	Seal	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	5	3
	Fuel Turbopump		4	6	8	8	8	8	8	8	8	8	8	8	8	8	8	8	5
	Oxidizer Turbopump		4	6	8	8	8	8	8	8	8	8	8	8	8	8	8	8	5
No. Active Rigs and Turbopumps	Fuel Turbopump		1	4	5	6	6	5	5	4	4	4	4	4	4	4	4	4	3
	Oxidizer Turbopump		1	4	5	6	6	5	5	4	4	4	4	4	4	4	4	4	3
	Bearing and Thrust Balance (Fuel/Oxidizer)	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
	Seal	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

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FIGURE 4.2.8.1-4 MAIN OXIDIZER AND FUEL TURBOPUMP DEVELOPMENT PROGRAM

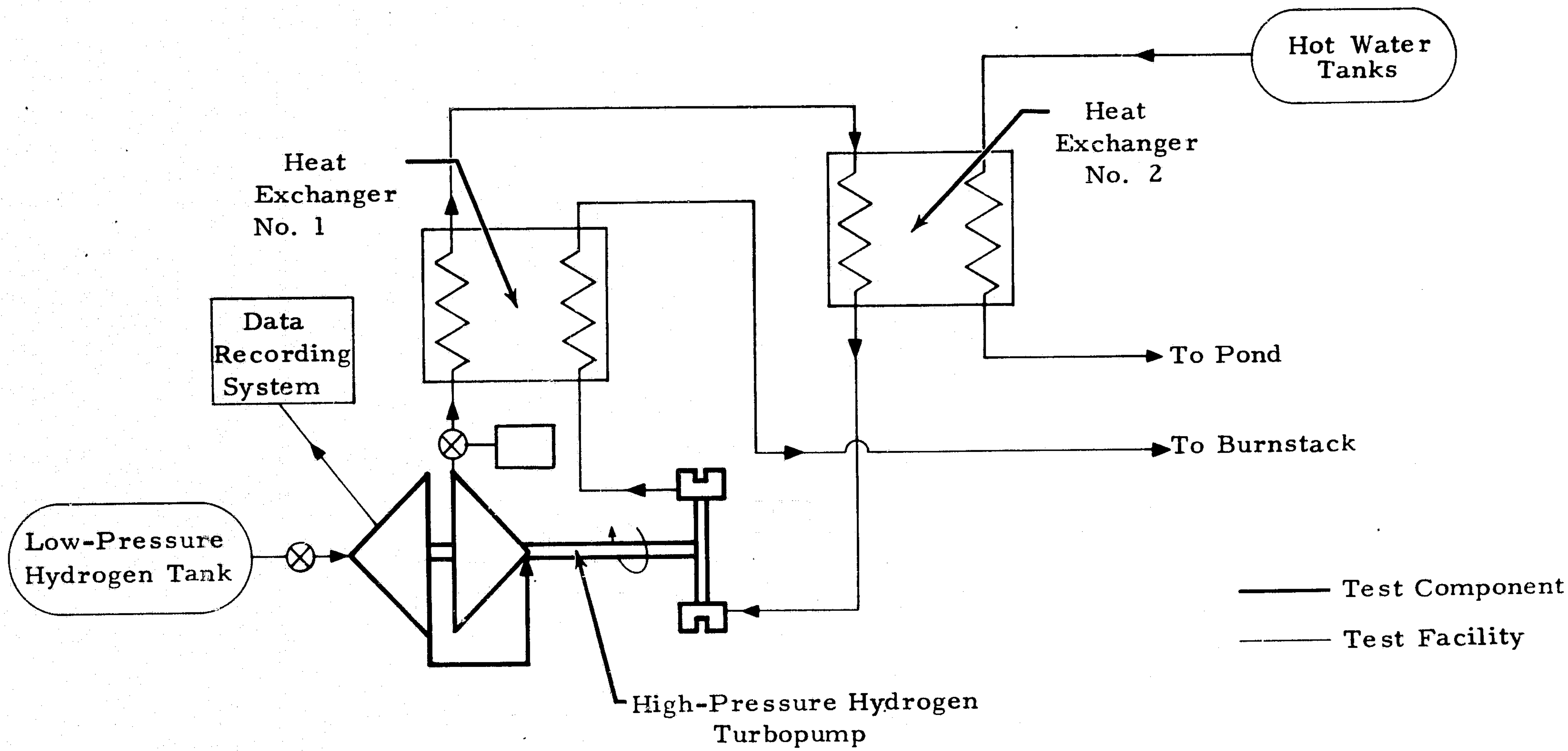

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FIGURE 4.2.8.1-5 HIGH-PRESSURE HYDROGEN TURBOPUMP TEST FACILITY SCHEMATIC

4.2.8.1 (Continued)

combine the low-speed inducer and simulated vehicle inlet plumbing to obtain an accurate simulation of the main pump inlet conditions. Turbine power will be supplied by a heat exchanger using gaseous hydrogen as a working medium. A schematic of the test facility is shown in Figure 4.2.8.1-6 to obtain performance data during the starting, transient, and steady-state operation, the turbopumps are instrumented to provide temperature, pressure, flow, vibration, and speed data. Starting tests will establish the propellant inlet conditions required to obtain pump performance consistent with engine requirements. Alternative designs of inducers, impellers, turbines, and cooling configurations, and alternative materials will be evaluated.

The primary objectives of the low-speed inducer development program will be to obtain the required component performance and reliability. The major milestones of the low-speed inducer development program with parts requirements are shown in Figure 4.2.8.1-7.

Water tests of the oxidizer low-speed inducers will be conducted with the flight design to assure the desired head-flow and suction specific speed characteristics prior to integrating the inducer into rig and engine tests. Performance evaluations will define the pressure-flow-efficiency characteristics of the inducers, particularly for the low-flow high-speed conditions that are required during engine starting. Tests will also be made to define the sensitivity of the inducer performance to variations in the propellant inlet conditions. The durability of the flight liftoff seal designs will be established through component and engine testing. Cyclic endurance tests to determine the fatigue life of the bellows assembly will be made. Turbine power will be provided by gaseous hydrogen for the fuel inducer and gaseous nitrogen for the oxidizer inducer. The oxidizer and fuel low-speed inducers may be tested with their respective main pumps.

The Thrust Vector Control (TVC) system for the main stage multichamber/plug engine system will consist of actuators which hinge the different engine modules to provide the lateral thrust vector. The lateral reactions from this type of system can be analytically determined with reasonable accuracy. (The toroidal/aerospike engine system, however, will use injection of liquid oxygen about the base of the plug to provide the necessary lateral force. This type of engine system is dependent upon specific configuration layouts and its performance is more sensitive to altitude effects. Anticipated lateral reactions as a function of injectant flow are difficult to determine analytically for the overall flight regime.) As no test facility will be provided for conducting tests of the overall main stage engine system and its associated TVC over the altitude range that will be encountered in flight, the first operational test of the thrust vector control system will be in conjunction with the first R&D flight test. Design of these systems therefore must rely on extensive model tests and analytical studies to assure successful operation during the initial flight test.

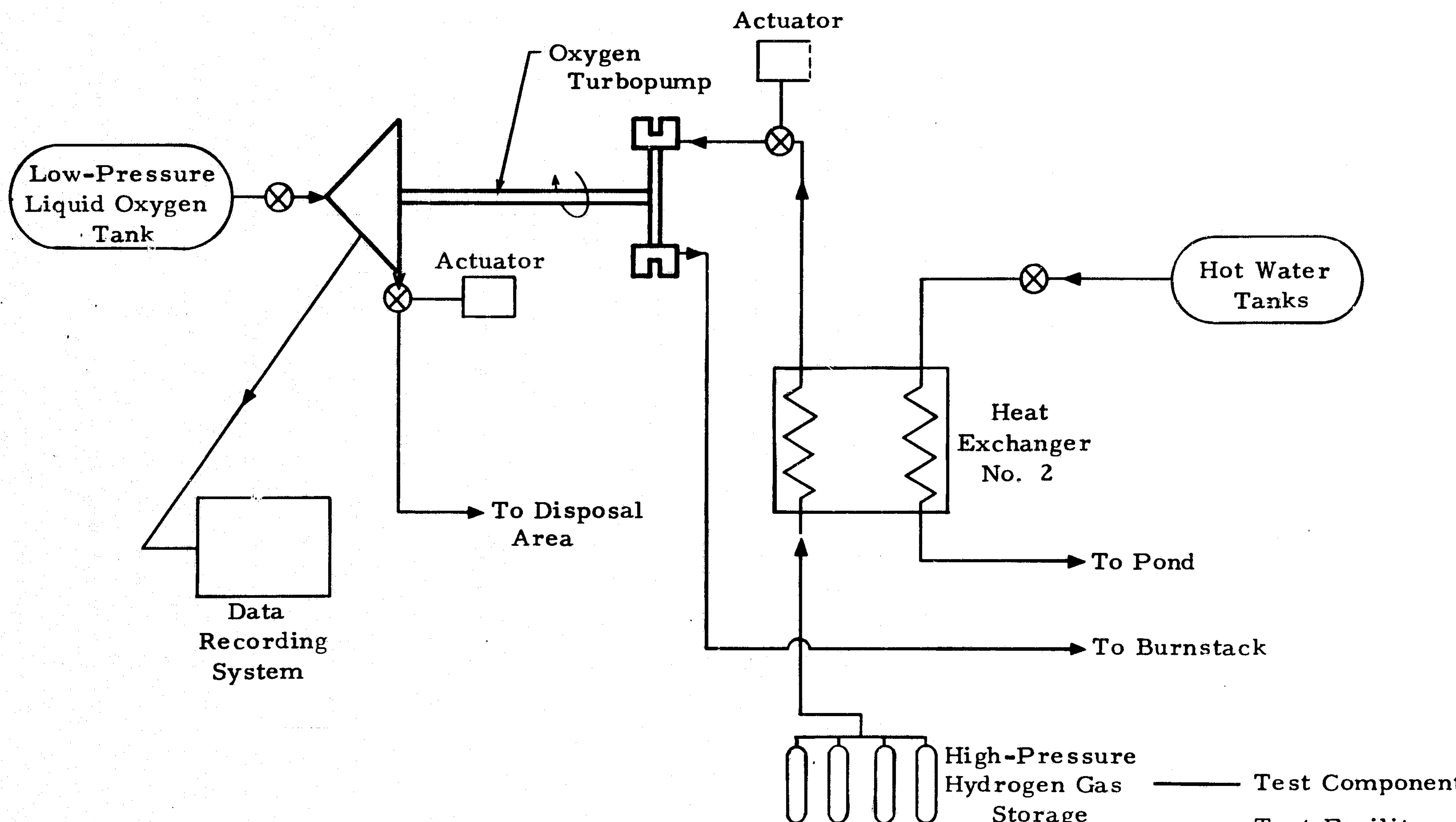

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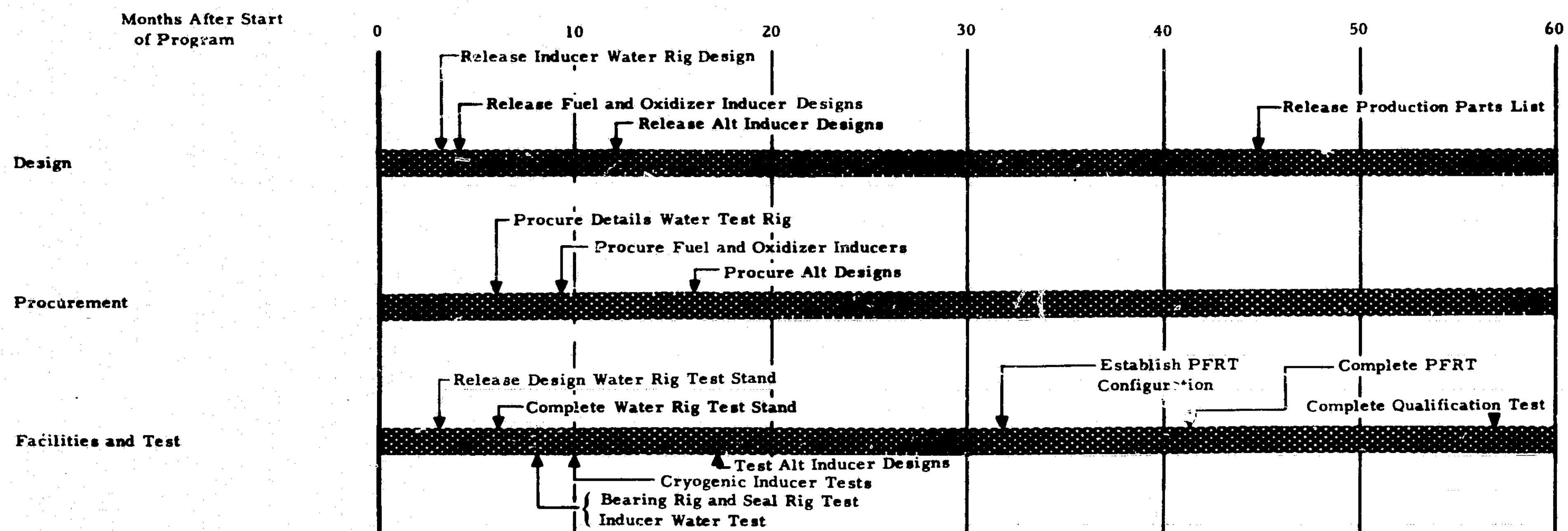
FIGURE 4.2.8.1-6 HIGH-PRESSURE OXYGEN TURBOPUMP TEST FACILITY SCHEMATIC



Hardware Incl Rigs (Equiv Sets Parts Per Quarter)	Fuel	2	2	3	3	2	2	2	2	2	2	2	2	2	1	1	0	1	0	0
	Oxidizer	2	2	3	3	2	2	2	2	2	2	2	2	2	1	1	0	1	0	0
Rig Tests (Per Quarter)	Water Rig		50	30	12															
	Fuel Inducer			10	10	8	8	8	8	8	8	8	8	8	8	8	8	8	8	6
	Oxidizer Inducer			10	10	8	8	8	8	8	8	8	8	8	8	8	8	8	8	6
	Brg - Fuel/Oxidizer		5/5	5/5	5/5	5/5	5/5	5/5												
Rig Rebuilds	Seal - Fuel/Oxidizer		5/5	5/5	5/5	5/5	5/5													
(Per Quarter)	Water Rig		15	10	5															
	Fuel Inducer			5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3
	Oxidizer Inducer			5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3
	Brg Fuel/Oxidizer		5/5	5/5	5/5	5/5	5/5	5/5												
	Seal Fuel/Oxidizer		5/5	5/5	5/5	5/5	5/5													
No. Active Inducers and Rigs	Fuel			2	4	5	5	4	4	4	4	4	3	3	3	2	2	2	2	1
	Oxidizer			2	4	5	5	4	4	4	4	4	3	3	3	2	2	2		1
	Brg - Fuel/Oxidizer		1/1	1/1	1/1	1/1	1/1	1/1												
	Seal - Fuel/Oxidizer		1/1	1/1	1/1	1/1	1/1													

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FIGURE 4.2.8.1-7 LOW-SPEED INDUCER DEVELOPMENT PROGRAM

4.2.8.1 (Continued)

The module control system development program plan is based on extensive design effort, analog simulation, and development testing to produce a reliable system compatible with the demands of a variable thrust, variable mixture ratio rocket engine with a specified time-between-overhauls (TBO).

To achieve these goals, the control system development program will be divided into two phases: 1) the development of transient and steady-state functional performance characteristics to meet engine and vehicle requirements, and 2) the development of mechanical performance that will provide the required engine durability and reliability.

Experience has shown that extensive test bench performance evaluation and development testing will minimize control problems during engine testing. Information obtained from this type of testing will be integrated into a computer simulation that ultimately will utilize these data in conjunction with engine test data to more fully define the design of the control system components.

Cyclic endurance testing of the control system springs and seals, as well as cyclic endurance tests of complete valve and computer assemblies under simulated operating conditions, will be conducted. Instrumentation will measure actuation pressures and valve position to determine if valve response is compatible with the engine start and shutdown sequence demands.

The test schedules, parts delivery schedule and facility requirements are shown in Figure 4.2.8.1-8.

Engine Module Development Program

At least 700 full-scale engine module firings, totaling at least 63,000 seconds of operation, are considered necessary at the time of completion of the PFRT. These tests will include simulated vehicle environments, propellant lines, and interfaces. This engine development program was estimated to consume the equivalent of 34 sets of engine parts through the PFRT portion of the program. An additional 1300 firings, totaling over 234,000 seconds, will be required at the time of completion of MQT. For this latter phase of the program, it was estimated that the equivalent of 23 sets of engine parts will be consumed. Figure 4.2.8.1-9 illustrates the details of the engine development program.

The primary objectives of the engine test program will be the development of the required engine performance, durability, and system reliability within the expected vehicle operating environment. To attain these objectives, tests of engines to the limits of their endurance and performance are planned. Deficiencies uncovered by these tests will then be rapidly eliminated by engine changes.

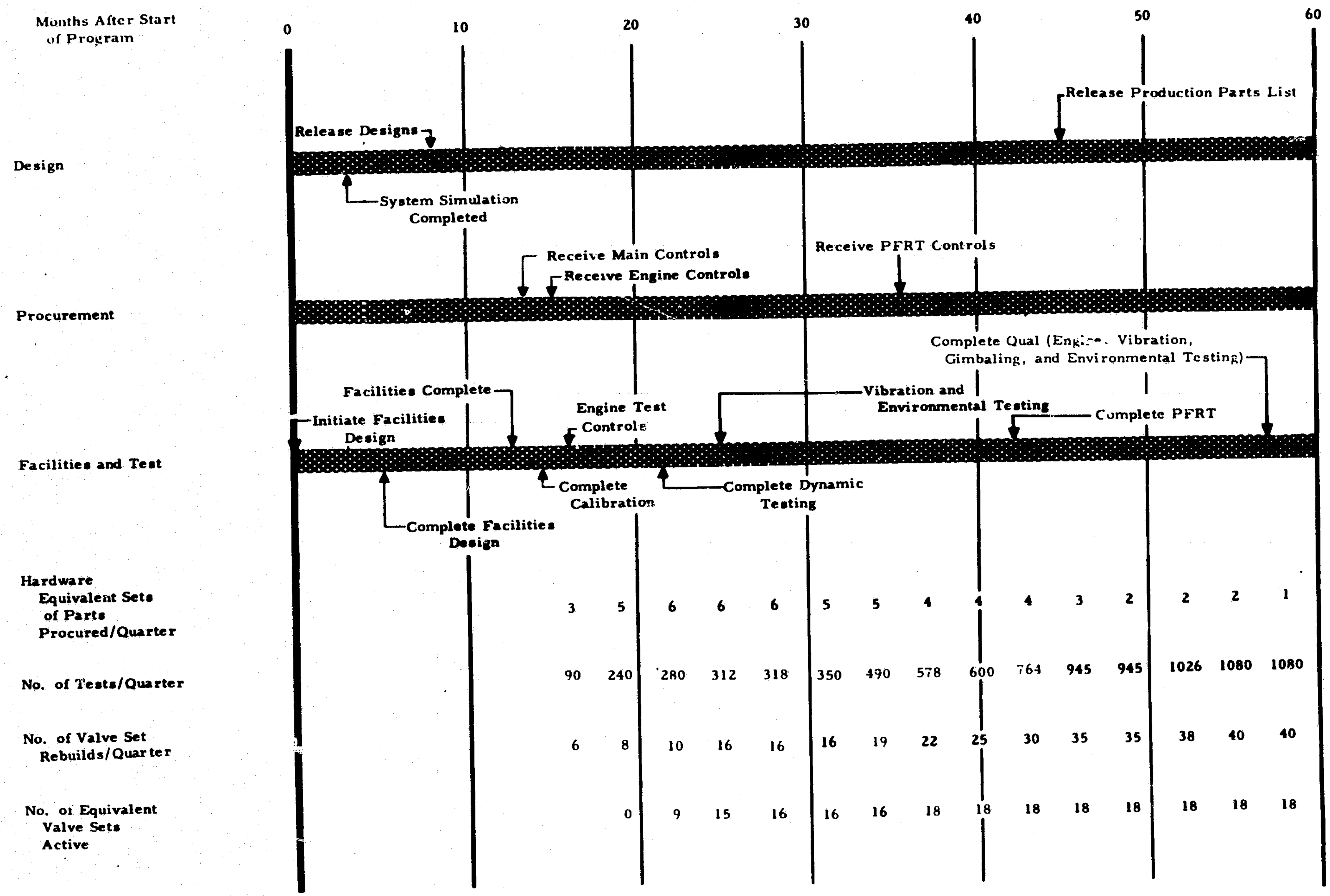
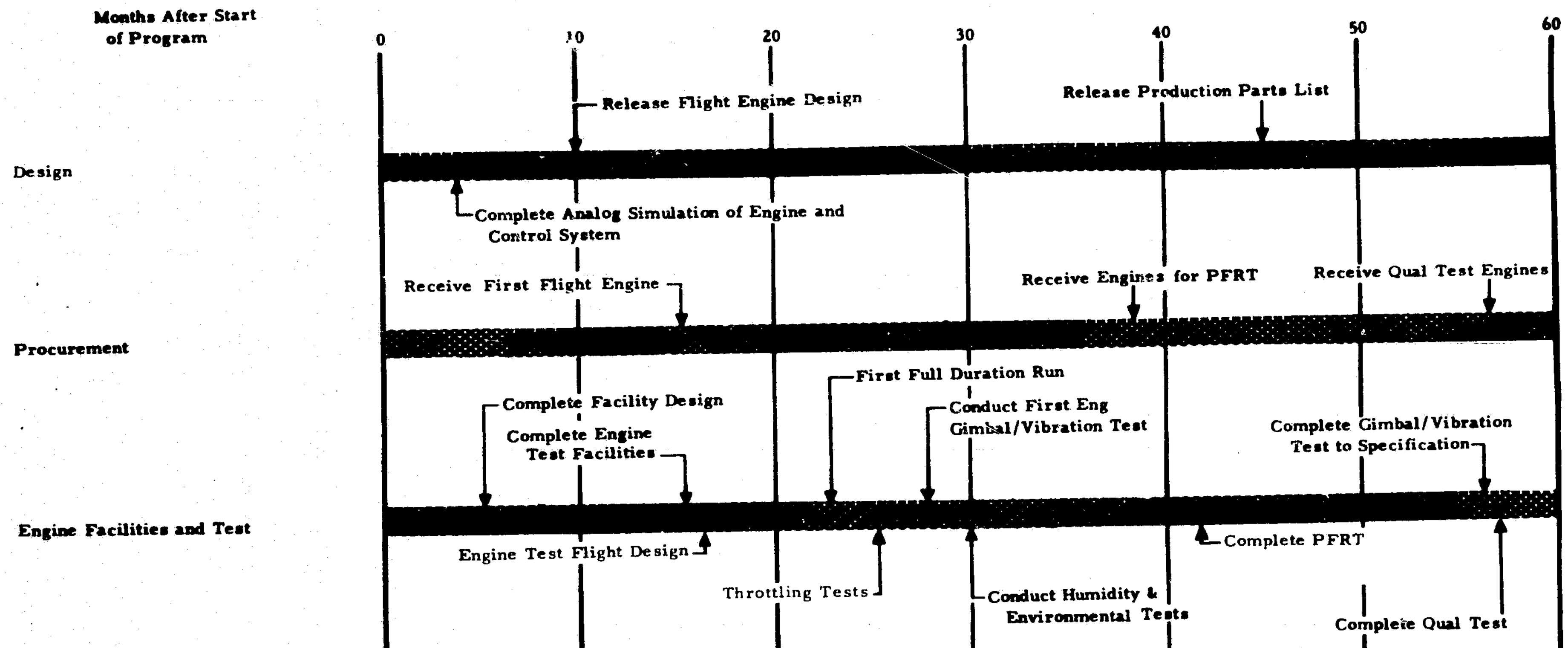


FIGURE 4.2.8.1-8 CONTROL SYSTEM DEVELOPMENT



Hardware in Equivalent Sets of Parts Procured/Quarter	2	2	2	2	2	3	4	4	4	4	4	5	5	4	4	2
No. of Tests/Quarter		32	40	50	60	65	80	110	120	143	170	200	245	245	245	195
No. of Engine Mounts/Quarter		8	10	15	18	21	22	28	30	35	35	35	38	39	40	32
No. of Engine Rebuilds/Quarter		8	11	16	19	20	20	24	28	36	38	38	41	43	43	30
No. of Active Engines		3	3	4	4	5	6	7	8	10	10	10	10	10	10	10

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FIGURE 4.2.8.1-9 ENGINE DEVELOPMENT PROGRAM

4.2.8.1 (Continued)

The major areas to be investigated are the interactions between the components and subsystems and the operation of components in the overall vehicle/engine system environment.

Testing of the engine module will include engine steady-state operation at all thrust levels throughout the throttling range of the engine and over the full mixture ratio range, as well as the start-to-idle and shutdown transients under both sea level and vacuum back pressure conditions. Engine performance, system stability, and durability tests at intermediate thrust levels, as well as full thrust conditions, will be conducted. Engine test facilities are required that will simulate high altitude pressure conditions at part power and during the start-transient. Engine tests are also planned with an atmospheric exhaust. Engine test facilities will include the capability to simulate the vehicle propellant feed system to investigate system dynamics during start and thrust transients.

Engine module testing with the complete control system is planned to develop the control system and resolve interactions that would not normally be detected during component testing. Tests to evaluate the capability of the control system to provide accuracy, repeatability, and stable engine module operation over the mixture ratio and thrust ranges. It will be required to demonstrate the suitability of the control system to maintain safe engine operation during accelerations and decelerations. Tests are planned to determine the effects of replacing control system and engine components on engine module performance and trim. Tests will demonstrate the capability of the engine to repeat mixture ratio and thrust level trim settings within the desired accuracy. Computer simulations of the engine and control system are planned to assist in the design phase of the program and will be maintained throughout the development program to study problems.

The repeatability of the ignition sequence, including delay time between activation of the igniters and the attainment of combustion will be substantiated by tests in which the propellant flow rates, spark rates, and combustion chamber pressures are measured. By establishing the ignition characteristics under simulated altitude and sea level starting conditions, the requirements for all flight modes will be investigated.

Quantitative measurement of leakage will demonstrate the adequacy of static seals. Measurements of propellant flows from system overboard vents during engine operation will be included. These data will assure compatibility of the engine module with the vehicle installation.

Engine module performance at all thrust levels and mixture ratios over the engine operating range will be established during the engine development program. Computer programs will assist in the reduction and analysis of these data. Flight instrumentation, as well as supplementary instrumentation, will establish component performance and overall engine performance.

4.2.8.1 (Continued)

Malfunction tests are planned to assure that the engine will operate or shut down safely without damage to the remainder of the vehicle after a failure or malfunction of the electrical power supply, control input signals, or propellant supply systems.

Environmental tests will assure that the engine can withstand the anticipated environmental conditions without structural failure, excessive static leakage, or performance deterioration. These environmental tests will include high and low temperature, salt atmosphere, gimbal, and vibration testing.

Prior to initiation of the PFRT or MQT, each engine module designated for these tests will be required to pass an Acceptance Test as specified in an engine model specification. These Acceptance Tests will include engine tests that demonstrate engine operation and performance in accordance with the engine model specifications.

PFRT testing will be conducted at the design thrust levels as specified in the engine model specifications. Testing will be required at sea level and simulated flight altitude conditions. The acceptance and calibration testing of the engine components at simulated service conditions in accorance with an engine model specification will be included.

After completion of the PFRT, the development effort will be directed to improving the performance and reliability, increase the service life, and support field and flight test programs. Engine module development after PFRT will include testing under simulated vehicle interface conditions to improve the engine/vehicle integration and overall system performance. Possible revisions to the control, electrical, pneumatic, and propellant interface conditions will be evaluated on a test stand that simulates the vehicle interface. The development through MQT is predicated on a high rate of engine testing with emphasis on full-duration tests. The engine systems development program will be supplemented by a series of environmental tests on the components and subsystems. These tests will evaluate the component performance and demonstrate the reliability of components under simulated service conditions, including acceleration loading, vibration, temperature, and pressure. All components will be required to complete the component testing as defined by the MQT requirements specified in an engine model specification, prior to initiation of the engine qualification testing. Engine qualification tests will be required that include the test durations and cycles over the range of environmental conditions specified in an engine model specification.

4.2.8.2 Resource Requirements

The following resource requirements outlined those requirements for development and qualification of the multichamber/plug engine module as provided by Pratt and Whitney. (Resource requirements for development of the toroidal/aerospike engine system are discussed in Section 9.0-Resource Requirements for Design Alternatives.)

4.2.8.2 (Continued)

Engine test facilities will be required to simulate high altitude pressure conditions at part power and during the start-transient. Engine tests are also planned with an atmospheric exhaust. Engine test facilities will include the capability to simulate the vehicle propellant feed system to investigate system dynamics during start and thrust transients. Existing test facilities and other new facilities required for recurring acceptance testing can be adapted to these tests for the individual engine modules.

The gross overall program costs for the engine test programs were provided by Pratt and Whitney. These costs were categorized by applying percentage factors against this gross cost. These percentage factors were developed from J-2 engine historical cost data.

Table 4.2.8.2-I shows the resulting costs for the AMLLV main stage engine module development, PFRT and qualification program. Table 4.2.8.2-II shows the required propellant and its associated cost for accomplishment of the AMLLV main stage engine module test program. Tables 4.2.8.2-III through -VIII show similar data for the AMLLV injection stage engine test program and for the MLLV main stage engine module and MLLV injection stage engine test programs respectively. Table 4.2.8.2-IX summarizes the above eight tables and shows total overall program cost for the liquid engine test programs.

Table 4.2.8.2-I. AMLLV MAIN STAGE ENGINE MODULE DEVELOPMENT AND TEST COSTS (MULTICHAMBER/PLUG)

"B" Costs	Component	Engine	PFRT	Qual.	Total
Engineering	$ 44.1M	$ 68.5M	$15.3M	$15.3M	$143.2M
Test	21.3M	25.1M	3.8M	3.8M	54.0M
Equipment	3.8M	11.4M			15.2M
Tooling (Basic)	3.8M	7.7M			11.5M
Fabrication	21.3M	84.6M	24.5M	24.5M	154.9M
Subtotal	$ 94.3M	$ 197.3M	$43.6M	$43.6M	$378.8M
Note: Engine Module Vacuum Thrust = 793,000 pounds.					

Table 4.2.8.2-II. AMLLV MAIN STAGE ENGINE MODULE PROPELLANT CONSUMPTION - PFRT AND QUALIFICATION TESTS (MULTICHAMBER/PLUG)

Oxygen/Hydrogen Mix Ratio ≈ 6:1 2,000 PFRT and Qualification Tests			
Total Consumption			2,350,000,000 LBS
Oxygen			2,014,285,715 LBS
Hydrogen			335,714,285 LBS
Cost			
Oxygen	$.015 X 2,014,285,715 LBS	=	$ 30,214,286
Hydrogen	$.25 X 335,714,285 LBS	=	83,928,571
	Total		$ 114,142,857

Table 4.2.8.2-III. AMLLV INJECTION STAGE ENGINE DEVELOPMENT AND TEST COSTS

"B" COSTS	Component	Engine	PFRT	Qual.	Total
Engineering	$ 24.0M	$ 37.0M	$ 8.3M	$ 8.3M	$ 77.6M
Test	11.5M	13.5M	2.1M	2.1M	29.2M
Equipment	2.0M	6.2M			8.2M
Tooling	2.0M	4.2M			6.2M
Fabrication	11.5M	45.7M	13.2M	13.2M	83.6M
Subtotal	$ 51.0M	$ 106.6M	$ 23.6M	$ 23.6M	$ 204.8M
Note: Engine Vacuum Thrust = 250,000 pounds.					

Table 4.2.8.2-IV. AMLLV INJECTION STAGE ENGINE MODULE PROPELLANT CONSUMPTION - PFRT AND QUALIFICATION TESTS

Propellant Consumption Inc. Ancillary Fluids Oxygen/Hydrogen Mix Ratio = 6:1 2,000 PFRT and Qualification Tests			
Total Consumption			740,000,000 LBS
Oxygen			634,285,715 LBS
Hydrogen			105,714,285 LBS
Cost			
Oxygen	\$.015 X 634,285,715 LBS	=	\$ 9,514,286
Hydrogen	\$.25 X 105,714,285 LBS	=	26,428,571
	Total		\$ 35,942,857

Table 4.2.8.2-V. MLLV MAIN STAGE ENGINE MODULE DEVELOPMENT AND TEST COSTS

"B" COSTS	Component	Engine	PFRT	Qual.	Total
Engineering	\$ 31.0M	\$ 48.2M	\$ 10.8M	\$ 10.8M	\$ 100.8M
Test	15.0M	17.6M	2.7M	2.7M	38.0M
Equipment	2.7M	8.1M			10.8M
Tooling (Basic)	2.7M	5.4M			8.1M
Fabrication	15.0M	59.6M	17.2M	17.2M	109.0M
Subtotal	\$ 66.4M	\$ 138.9M	\$ 30.7M	\$ 30.7M	\$ 266.7M

Note: Engine Module Vacuum Thrust = 408,000 pounds.

Table 4.2.8.2-VI. MLLV MAIN STAGE ENGINE PROPELLANT CONSUMPTION - PFRT AND QUALIFICATION TESTS

Propellant Consumption Inc. Ancillary Fluids Oxygen/Hydrogen Mix Ratio = 6:1 2,000 PFRT and Qualification Tests			
Total Consumption			1,210,000,000 LBS
Oxygen			1,037,142,857 LBS
Hydrogen			172,857,143 LBS
Cost			
Oxygen	$.025 X 1,037,142,857 LBS	=	$ 15,557,143
Hydrogen	$.25 X 172,857,143 LBS	=	43,214,286
	Total		$ 58,771,429

Table 4.2.8.2-VII. MLLV INJECTION STAGE DEVELOPMENT AND TEST COSTS

"B" COSTS	Component	Engine	PFRT	Qual.	Total
Engineering	$ 16.4M	$ 25.6M	$ 5.7M	$ 5.7M	$ 53.4M
Test	8.0M	9.3M	1.4M	1.4M	20.1M
Equipment	1.4M	4.3M			5.7M
Tooling	1.4M	2.9M			4.3M
Fabrication	8.0M	31.6M	9.2M	9.2M	58.0M
Subtotal	$ 35.2M	$ 73.7M	$ 16.3M	$ 16.3M	$ 141.5M

Note: Engine Vacuum Thrust - 125,000 pounds.

Table 4.2.8.2-VIII. MLLV INJECTION STAGE PROPELLANT CONSUMPTION - PFRT AND QUALIFICATION TESTS

Propellant Consumption Inc. Ancillary Fluids Oxygen/Hydrogen Mix Ratio = 6:1 2,000 PFRT and Qualification Tests 125K Thrust				
<u>Total Consumption</u>				370,000,000 LBS
Oxygen				317,142,858 LBS
Hydrogen				52,857,142 LBS
<u>Cost</u>				
Oxygen	\$.015 X 317,142,858 LBS	=	\$ 4,757,143	
Hydrogen	\$.25 X 52,857,142 LBS	=	13,214,286	
	Total		\$ 17,971,429	

Table 4.2.8.2-IX. MAIN AND INJECTION STAGE ENGINE MODULE DEVELOPMENT COST SUMMARY (MULTICHAMBER/PLUG)

	AMLLV	MLLV
1. Main Stage Engine Modules	\$378,800,000	\$266,700,000
Propellant	114,142,857	58,771,429
2. Injection Stage Engine Modules	204,800,000	141,500,000
Propellant	35,942,857	17,971,429
TOTALS	\$733,685,714	\$484,942,858

4.2.9 Solid Rocket Motor Stage (SRM's) Development Tests

This section defines the SRM development and PFRT test program. The SRM stage attach structure will be manufactured at the Michoud stage manufacturing facility. Three sets of this hardware will be shipped to the solid rocket motor (SRM) manufacturing facility for final assembly and testing with other SRM stage components.

4.2.9.1 Test Description

a. Propellant Raw Material Tests

All raw materials used in the propellant formulation will be analyzed and standards for acceptance established.

b. Components Tests

All of the following major components will be subjected to individual development tests:

1. Forward and aft skirts
2. Attachment structure
3. Separation motors
4. Safe and arm mechanism
5. Ignition system
6. Destruct system
7. Electrical systems
8. Instrumentation systems
9. Thrust vector control system
10. Heat shield
11. Raceway
12. Environmental control ducts
13. Mountings and fairings
14. Attachment structure separation system

4.2.9.1 (Continued)

Each of the above items will be subjected to additional functional test checks to obtain performance and reliability data.

c. Solid Motor Stage Development Tests

Four 260-inch motors will be static tested during the development program. These tests will verify the performance and structural integrity of the solid motor; provide thermal,acoustical and vibration data; and provide reliability data.

d. SRM Preliminary Flight Rating Tests (PFRT)

Six motors will be subjected to Preliminary Flight Rating Tests (PFRT) testing. At least three of these tests will include a complete stage system assembled to the motor (with exception of the nose cone) to provide additional data beyond that obtained in the above component tests. These tests will verify the final design and provide increased confidence level to the reliability estimate.

SRM/Transportation Equipment Integration Test

The SRM/Transportation Equipment Integration Test will be performed to satisfy the following objectives:

a. Demonstrate that the transportation dynamic loading criteria for the SRM stage, as defined by the approved SRM stage design criteria, is not exceeded while loaded in defined transportation equipment and while being subjected to dynamic loading conditions which simulate actual land and sea dynamic loading conditions.

b. Demonstrate that the transportation equipment such as tie downs, transportation harnesses and dollies, mounting provisions, shock absorbers and transportation barge equipment survive and function in accordance with their approved design criteria under systems operation, and while being subjected to controlled maximum dynamic environment.

c. Demonstrate that the specification requirements for the transportation equipment are compatible with the specification requirements of the SRM stage.

An operationally configured inert propellant SRM stage will be positioned in its operationally configured transportation equipment. Instrumentation will be calibrated and data acquisition system will be connected, calibrated, and end to end checked. The test specimen including Data Acquisition System will be transported

4.2.9.1 (Continued)

by barge for a sea transportation test. Sufficient test runs will be accomplished to evaluate all critical modes as defined by the contractor and concurred in by the customer.

Tests shall demonstrate extent of compliance only. Redesign or retest requirements shall be negotiated. Test data shall be limited to stress, strain, displacement, acceleration, velocity, temperature, and humidity measurements. The quantities, ranges, accuracies, etc., of these data shall be defined at a later date. However, as a limiting factor, the Data Acquisition System shall be capable of recording 100 channels of data per run and shall have a capability of providing quick look data.

4.2.9.2 Resource Requirements

SRM Costs for Development Testing

The following Tables 4.2.9.2-I through 4.2.9.2-IV show the development costs for the 260 inch SRM stages for the AMLLV and MLLV. These figures were compiled by Aerojet-General and Boeing/Michoud. They cover the complete period of development and testing of the AMLLV/MLLV and SRM stages through the two planned R&D test flights.

4.2.10 Flight Tests

Final qualification of a rocket boost system can only be realized when the booster is used in a mode that duplicates the operational environments. When a boost system is to be man-rated, some un-manned flights must precede the manned flights in order to qualify the system. In the Saturn V program, two flights were considered adequate; therefore, two successful flights of the maximum size vehicle (for any given AMLLV or MLLV program) will be assumed adequate for the R&D program.

4.2.10.1 Test Description

Each R&D flight test includes the launch of a highly instrumented booster vehicle with either a simulated or unmanned payload. Because of the extra instrumentation and communication equipment required for sending data to the ground stations, the usable payload is reduced. Use of these test vehicles to deliver unmanned payloads to orbit can be considered as a program bonus if the risk of losing the payload is not critical. This study does not consider the cost or value of this facet, but assumes the payload is government furnished.

Flight verification tests, unmanned, will demonstrate safe functioning and achievement of minimum performance requirements of the components of a vehicle or spacecraft system, when exposed to unmanned operating conditions, to the extent that the vehicle can be man-rated.

TABLE 4.2.9.2-I SRM DEVELOPMENT TESTING COST SUMMARY - AMLLV & MLLV

NON-RECURRING - DEVELOPMENT TESTING		
	AMLLV (1)	MLLV (1)
1. Dev./PFRT Program		
Motor	$ 86,951,000	$ 69,321,000
Stage	34,684,000	33,037,000
2. Other Program Costs	16,133,000	14,758,000
3. Mfg. Development for Attach Hdw.	126,000	118,000
TOTALS	$137,894,000	$117,234,000

(1) SRM Contractor's (Aerojet-General) Input

TABLE 4.2.9.2-II SRM PREFLIGHT RATING TESTING - AMLLV & MLLV

NON-RECURRING

DEVELOPMENT TESTS
DEV/PFRT

			AMLLV (1)	MLLV (1)
	Motor Costs	Quantity	Cost	Cost
1.	Chamber	10	$26,397,000	$20,374,000
2.	Nozzle:			
	Shell	10	12,650,000	5,446,000
	Ablataves & Exit Cone	10	10,401,000	9,372,000
	Actuators (2 Motors)	10 Sets	872,000	858,000
	APU (2 Motors)	10 Sets	1,543,000	1,509,000
3.	Case Installation	10	1,628,000	1,605,000
4.	Propellant and Liner Materials		15,345,000	11,966,000
5.	Igniter	12	434,000	357,000
6.	Shipping	10	1,698,000	1,297,000
7.	Manufacturing Labor			
	Process and Test	10	6,067,000	4,875,000
	Inspection	10	1,779,000	1,428,000
	Subtotal		$78,814,000	$61,252,000
	Test Facilities		8,137,000	8,069,000
	Total Aerojet Development Motor Cost Less Fee		$86,951,000	$69,321,000

(1) AEROJET INPUT, OCTOBER 31, 1968

TABLE 4.2.9.2-III SRM PFRT STAGE COMPONENTS - AMLLV & MLLV

NON-RECURRING - PFRT

*STAGE COMPONENTS		AMLLV	MLLV
1. Structural Components			
Heat Shield	$2,070,000		
Raceway (Tunnel)	620,000		
Environmental Control Ducts	410,000		
Mounting and Fairings	2,220,000	$ 5,300,000	$ 5,300,000
2. Electrical System		9,400,000	9,400,000
3. Instrumentation		11,000,000	11,000,000
4. Stage Separation Components Initiation Components		280,000	280,000
5. Destruct Charges and Firing Components		298,000	298,000
6. Forward Attach Structure		5,532,000	4,395,000
7. Aft Attach Structure		1,668,000	1,353,000
8. Fittings		1,206,000	1,011,000
TOTAL STAGE COST		$34,684,000	$33,037,000

*Costs are for three complete sets of stage components used in PFRT Program by Aerojet

TABLE 4.2.9.2-IV SRM PFRT DEVELOPMENT COSTS - AMLLV AND MLLV

OTHER PROGRAM COSTS

DEVELOPMENT TESTS

DEV/PFRT

	AMLLV (1)	MLLV (1)
1. Labor		
Management & Administration	$ 1,578,000	$ 1,538,000
Engineering	7,597,000	7,173,000
Test Equipment Design	233,000	242,000
2. Component Development	4,982,000	4,097,000
3. Special Test Equipment	1,100,000	1,065,000
Subtotal	$15,490,000	$14,115,000
Test Facilities	643,000	643,000
TOTAL COSTS LESS FEE	$16,133,000	$14,758,000

(1) AEROJET INPUT, OCTOBER 31, 1968

4.2.10.1 (Continued)

The prime objectives of flight tests are:

a. Evaluation of hardware characteristics and operational procedures which cannot be adequately evaluated by ground testing.

b. Acquisition of flight data and correlation of these data with the results of ground tests.

c. Flight verification of the launch vehicle and ground support equipment prior to manned flight.

d. Flight verification of stage subsystems affecting crew safety prior to manned flight.

e. Ground crew training.

Prerequisites that will be satisfied before launch of each R&D flight are:

a. Ground qualification, reliability demonstration and certification of flight worthiness. This will include static test firing of each stage on the launch pad, and refurbishment, prior to vehicle stacking for launch. (See Section 7.0, Launch Operations Plan.)

b. Flight verification of critical equipment.

c. Each flight space vehicle will be as complete as practicable; i.e., no dummy stage, modules or subsystems, with the exception of a simulated payload.

4.2.10.2 Resource Requirements

The flight test vehicle will consist of a main stage and a GFE simulated payload with an instrument unit, plus injection stage module(s) and SRM stages where applicable. The estimates for specimens, launch operations and propellants have been modularized to facilitate costing of the various vehicle configurations for each of the AMLLV and MLLV programs.

Individual stage (specimen) costs were obtained from the "C" category estimates with allowances for the additional R&D instrumentation.

Transportation of the test specimen elements, from factory to the launch site, is included in the specimen cost.

Estimates were provided for specimen costs, engineering manhours, non-engineering manhours, launch facility maintenance, and expendibles used for processing each R&D flight test vehicle through a complete cycle. These estimates are shown in Table 4.2.10.2-I for the AMLLV and Table 4.2.10.2-II for the MLLV. From these inputs, total R&D flight test costs were developed and are shown in Tables 4.2.10.2-III through 4.2.10.2-VI.

TABLE 4.2.10.2-I AMLLV FLIGHT TEST RESOURCE ESTIMATES

ITEM	MAIN STAGE + I U	INJECTION STAGE ENGINE MODULE	INJECTION STAGE FUEL MODULE	12 SRM STRAP-ON STAGE	MAIN STAGE + IU + 3 MODULE INJECTION + 12 SRM'S
● ENGINEERING MANHOURS	1,249,000 m/h	102,000 m/h	32,000 m/h	161,000 m/h	1,544,000 m/h
● NON-ENGINEERING MANHOURS	19,121,000 m/h	1,580,000 m/h	504,000 m/h	2,368,000 m/h	23,573,000 m/h
LAUNCH FACILITY MAINTENANCE/LAUNCH	$8,750,000	-0-	-0-	$1,150,000	$9,900,000
* EXPENDIBLES	$4,905,000	$545,000	$545,000	-0-	$6,540,000

NOTE: These Launch Operations resource requirements for the R&D flight tests were developed from the operational flight launch operations resource requirements provided by BATC. (See Section 7.0). The former requirements reflect the increased launch cycle time (9 mos.), and the increased instrumentation required for the R&D flight vehicles.

*Without Burden

TABLE 4.2.10.2-II MLLV FLIGHT TEST RESOURCE ESTIMATES

ITEM	MAIN STAGE + I U	INJECTION STAGE- ENGINE MODULE	INJECTION STAGE- FUEL MODULE	SRM STRAP-ON STAGE (8)	MAIN STAGE + IU + 3 MODULE INJECTION + 8 SRM'S
● ENGINEERING MANHOURS	1,195,000m/h	101,000m/h	28,000 m/h	126,000m/h	1,450,000 m/h
● NON-ENGINEERING MANHOURS	18,296,000m/h	1,536,000m/h	43,000m/h	1,928,000m/h	22,191,000m/h
LAUNCH FACILITY MAINTENANCE/LAUNCH	$8,750,000	-0-	-0-	$1,150,000	$9,900,000
EXPENDIBLES *	$2,452,875	$272,542	$272,542	-0-	$3,270,500

NOTE: These Launch Operations resource requirements for the R&D flight tests were developed from the operational flight launch operations resource requirements provided by BATC. (See Section 7.0). The former requirements reflect the increased launch cycle time (9 mos.), and the increased instrumentation required for the R&D flight vehicles.

* WITHOUT BURDEN

TABLE 4.2.10.2-III SINGLE-STAGE-TO-ORBIT COSTS - R&D FLIGHTS

COST ELEMENTS	AMLLV		MLLV	
R&D FLIGHT	# 1	# 2	# 1	# 2
Flight Stages	$188,611,000	$171,730,000	$146,216,000	$133,186,000
Propellants	6,573,000	6,573,000	3,287,000	3,287,000
Instrument Unit (IU)	9,346,000	9,346,000	9,346,000	9,346,000
Instrumentation (R&D)	24,555,000	24,555,000	24,324,000	24,324,000
Payload	GFE	GFE	GFE	GFE
Launch Maintenance	8,750,000	8,750,000	8,750,000	8,750,000
Launch Operations	174,324,000	174,324,000	165,856,000	165,856,000
SDF	6,169,000	6,169,000	6,169,000	6,169,000
Systems Evaluation & Integration (SE&I)	8,480,000	8,480,000	8,480,000	8,480,000
* TOTAL COSTS	$426,808,000	$409,927,000	$372,428,000	$359,398,000

* Includes Transportation, Facility and Equipment Maintenance Costs

TABLE 4.2.10.2-IV INJECTION STAGE ENGINE MODULE COSTS - R&D FLIGHTS

COST ELEMENTS	AMLLV		MLLV	
R&D FLIGHT	# 1	# 2	# 1	# 2
Flight Stages	$24,210,000	$22,298,000	$19,444,000	$17,855,000
Propellant	730,000	730,000	365,000	365,000
Instrument Unit	NC	NC	NC	NC
Instrumentation (R&D)	5,988,000	5,988,000	5,775,000	5,775,000
Payload	GFE	GFE	GFE	GFE
Launch Operations	10,731,000	10,731,000	9,491,000	9,491,000
Systems Evaluation & Integration (SE&I)	**	**	972,000	972,000
* TOTAL COSTS	$41,659,000	$39,747,000	$36,047,000	$34,458,000

* Includes Transportation, Facility and Equipment Maintenance Costs

** Included in Launch Operations ($972,000)

TABLE 4.2.10.2-V INJECTION STAGE FUEL MODULE COSTS - R&D FLIGHTS

COST ELEMENTS	AMLLV		MLLV	
R&D FLIGHT	# 1	# 2	# 1	# 2
Flight Stages	$13,242,000	$12,050,000	$ 9,596,000	$ 8,732,000
Propellant	730,000	730,000	365,000	365,000
Instrument Unit	NC	NC	NC	NC
Instrumentation (R&D)	NC	NC	NC	NC
Payload	GFE	GFE	GFE	GFE
Launch Operations	5,323,000	5,323,000	4,565,000	4,565,000
Systems Evaluation & Integration (SE&I)	NC	NC	NC	NC
* TOTAL COSTS	$19,295,000	$18,103,000	$14,526,000	$13,662,000

* Includes Transportation, Facility and Equipment Maintenance Costs

TABLE 4.2.10.2-VI SOLID ROCKET MOTOR (SRM) STRAP-ON COSTS - R&D FLIGHTS

COST ELEMENTS	AMLLV		MLLV	
R&D FLIGHT	# 1	# 2	# 1	# 2
Flight Stages	(1) $138,633,000	(1) $126,389,000	(2) $ 78,087,000	(2) $ 71,464,000
Delta - Forward Skirt	4,630,000	4,630,000	2,950,000	2,950,000
Instrument Unit	NC	NC	NC	NC
Instrumentation (R&D)	16,704,000	16,704,000	11,136,000	11,136,000
Payload	GFE	GFE	GFE	GFE
Launch Operations	8,209,000	8,209,000	8,092,000	8,092,000
Launch Maintenance	1,150,000	1,150,000	**	**
Systems Evaluation & Integration (SE&I)	1,150,000	1,150,000	1,150,000	1,150,000
* TOTAL COSTS	$180,808,000	$168,534,000	$113,473,000	$106,850,000

* Includes Transportation
Facility and Equipment
Maintenance Costs

(1) Cost for 12 SRM stages.

(2) Cost for 8 SRM stages.

** Included in Instrumentation ($1,150,000)

4.2.11 Ground Support Equipment (GSE) and Launch Vehicle Ground Support Equipment (LVGSE) Test

This section defines the specific ground tests which must be performed on all GSE/LVGSE equipment. These tests are grouped under five major test phases:

a. Acceptance Phase (nonrecurring);
b. Operational Development Phase (nonrecurring);
c. System Integration Phase (nonrecurring);
d. LVGSE Pre-Launch Checkout Phase (nonrecurring and recurring);
e. LVGSE Post-Launch Checkout Phase (recurring).

These major test phases and the specific ground tests applicable to each phase are described in subsequent paragraphs. The tests are generally applicable to GSE at the manufacturing test facilities, and to LVGSE at the launch site.

4.2.11.1 Test Description

Acceptance Phase - The GSE/LVGSE Acceptance Phase will encompass all testing performed on equipment prior to delivery to the procuring agency. Implementation of these tests will be the responsibility of the hardware contractor as specified in subsidiary test plans or contract specifications. The procuring agency will establish contractually the prerogative to select (on a random or planned basis) hardware produced by the contractor, and subject it to independent verification and inspection tests. The various tests that may be performed during this phase will include, but not be limited to, the following:

a. Structural Tests - Qualification tests to determine the ability of equipment to withstand predicted or measured static and dynamic forces to be encountered in operational use, assembly, storage, transportation, and handling;

b. Environmental Tests - Production acceptance tests on equipment performed under environmental rigors other than ambient for the prime purpose of verifying the quality of ground equipment;

c. Quality Assurance Tests - Any planned and systematic pattern of testing, including in-process tests, to provide adequate confidence that the equipment will perform in actual operations;

d. Qualification Tests - Any tests of GSE/LVGSE parts, components, subassemblies and subsystems which are performed to demonstrate that the design is inherently capable of meeting established requirements;

4.2.11.1 (Continued)

e. Reliability Tests - Any tests of GSE/LVGSE parts, components, subassemblies and subsystems performed to demonstrate that the hardware will perform its required functions under designated conditions and time for a specified operating period;

f. Electromagnetic Interference Tests - Any tests of equipment performed to determine the presence of unwanted electrical or magnetic fields;

g. Functional Tests - Any tests of equipment performed to demonstrate that the item operates as specified;

h. Development Tests - Any tests of equipment performed to ascertain design feasibility and suitability. These tests are conducted under simulated or actual environmental conditions;

i. Acceptance Tests - Any tests performed on equipment prior to delivery to ascertain conformance to contractual specifications. Successful completion of these tests will serve as the basis for acceptance of the contract end item by the NASA procuring agency.

Operational Development Phase - This phase of testing covers those operational development tests that will be conducted on the GSE/LVGSE at the various contractor/NASA facilities. These facilities encompass the System Development Breadboard Facility, Swing Arm Umbilical Test Facility and the various facilities that utilize the computer systems for programming and control.

The System Development Breadboard Facility (SDBF) will be used to verify the MLLV Automation Plan, and the adequacy of the LVGSE during test operations. All LVGSE allocated to SDBF that is common to that delivered to the Launch Complex will be representative quality hardware that has met all specified test requirements.

The Swing Arm Test Facility will be used to verify the adequacy of the launcher swing arms and tail service mast operations. This includes verification of the coupling, decoupling, and retraction of the umbilical carriers. Requirements for testing umbilical carriers following installation will be specified in subsidiary test plans. NASA will have the prime responsibility for implementation of all test activities at this facility.

Computer systems will be utilized throughout the AMLLV/MLLV test program to insure effective testing through automation. Computer systems requirements for test activities will be specified in subsidiary test plans.

System Integration Phase - This phase of testing will encompass the installation, checkout, integration, and qualification of all GSE at the manufacturing and test

4.2.11.1 (Continued)

complexes and of LVGSE installed at the Launch Complex. These tests will be conducted for the purpose of checking out, grooming, calibrating, and assessing the performance of the overall GSE/LVGSE systems. LVGSE contractors will provide NASA with technical support as prescribed. It is planned that certain of these tests will require the utilization of the facility checkout vehicle and simulators. The tests to be performed in this phase will be divided into four categories as follows:

a. GSE/LVGSE Checkout Tests - These test will ensure that each functional GSE/LVGSE subsystem is adequately checked out and groomed;

b. GSE/LVGSE Operability Tests - These tests will ensure that each functional GSE/LVGSE subsystem meets the AMLLV/MLLV program requirements as they relate to operability and performance. In general, these tests are conducted to determine adequacy of individual subsystems to support overall GSE/LVGSE systems testing. Final calibration of each subsystem will occur at this time. The LVGSE tests will be directed by NASA with technical support from contractors as required;

c. GSE/LVGSE System Functional Transmission Tests - These tests will determine inter and intra GSE/LVGSE subsystem compatibility as it pertains to physical and functional interfaces. In general, these tests will utilize simulated inputs to evaluate each command, monitored or recorded function from source to final recipient;

d. GSE/LVGSE System Qualification and Performance Tests - These tests will determine overall GSE/LVGSE system performance and compatibility with the facility (F) vehicle as they relate to physical, functional, electrical and mechanical interfaces. In general, these tests will be conducted with the facility vehicle and simulators. Upon successful completion of these tests, the GSE/LVGSE will be considered ready to support AMLLV/MLLV operations at the manufacturing test facilities or Launch Complex.

LVGSE Pre-launch Checkout Phase - This phase of testing will cover the operational tests that are performed on the LVGSE after the equipment has been installed and has successfully completed the preceding test phases. The implementation of these tests will be the prime responsibility of NASA with support from contractors as required.

These tests will be conducted for the purpose of verifying the compatibility and capability of the LVGSE for operational use with operational flight vehicles. It is intended that these tests will be performed on the facility (F) vehicle. The tests to be performed during this phase will be divided into four elements as follows:

4.2.11.1 (Continued)

a. Launch Vehicle GSE Functional Tests - These tests will be performed on operational LVGSE to verify that the equipment is ready for interfacing with the first launch vehicle. These tests and test documentation will be the prime responsibility of NASA. Contractor technical support for these tests will be determined by NASA;

b. LVGSE Compatibility Tests - These tests will be performed primarily to verify the compatibility of LVGSE with the ground and first launch vehicle. These tests will provide assurance that the LVGSE is operationally compatible prior to checkout of the launch vehicle. These tests will be the prime responsibility of NASA;

c. LVGSE Special Tests - These tests will be performed to encompass those areas in which certain unique application of LVGSE is involved. In general, these tests will be conducted for special evaluation of LVGSE. These tests will be the responsibility of NASA;

d. Pre-Use Checkout and Verification - As a minimum, the following ground support equipment checkout requirements must be fulfilled:

   1. Ground support equipment at the installation site will be checked out initially through self-verification or other appropriate means prior to connection with each item of space vehicle hardware. After connection of ground support equipment to space vehicle items, a systems compatibility check will be made prior to beginning the checkout of the space vehicle items,

   2. Subsequent pre-use checkouts will be performed prior to each launch to verify the readiness of the ground support equipment,

   3. Final verification tests of the ground support equipment will be performed during subsequent flights of unmanned or manned space vehicles.

LVGSE Post-Launch Checkout Phase - This phase of testing will cover those operations to be performed on the LVGSE after the vehicle has been launched, and to prepare the LVGSE to support the next launching. This will include refurbishment and modification operations, LVGSE verification tests, and pre-use tests. Testing will be performed to verify functional integrity of the LVGSE that was refurbished, modified, or replaced. This phase will be the responsibility of NASA with the support of contractors as required.

Functional tests will be conducted on the LVGSE following refurbishment, modification, or introduction of new equipment. These tests will be conducted to verify

4.2.11.1 (Continued)

functional integrity of the LVGSE. NASA will have prime responsibility for functional tests and will be supported by contractors as required.

Verification tests are system tests that are required to assure compatibility of modified or newly introduced LVGSE within the launch complex. NASA will have the prime responsibility for verification tests and will be supported by contractors as required.

4.2.11.2 Resource Requirements

Resource requirements for ground support equipment (GSE) at the manufacturing and test facilities, and launch vehicle ground support equipment (LVGSE) at the static firing and launch facility are generally covered in the test plans for these complexes. In other cases the test costs, in particular those for acceptance testing, are included in the hardware procurement costs and are not identifiable. The foregoing test plan was prepared to guide the orderly development of ground support equipment, and to assist in costing this ground support equipment at the various areas of usage.

4.3 MANUFACTURING AND OPERATION TESTS (RECURRING TESTS)

This section of the test plan describes the recurring tests applicable to the AMLLV and MLLV launch vehicle families (see prior Table 4.1.1.0-I). Figure 4.3.0.0-1 depicts the flow of these tests and shows the number of the applicable sections where the tests are discussed in detail. Acceptance tests shown are applicable to all elements of the vehicle families, i.e., the main stage, injection stage and the strap-on stages, and to their respective components and subassemblies. Resource requirements for these tests are not shown in this section as these tests are an integral part of the manufacturing process, and the resource requirements are included in the resource requirements for the manufacturing plan in the following Section 5.0. The main and injection stage static firing test resource requirements over and above those required for launch of the vehicle are shown. The resource requirements for the SRM stage sub-systems and systems test are discussed. The resource requirements for the pre-launch test and checkout are discussed in the subsequent launch plan in Section 7.0.

4.3.1 General Acceptance Tests

Acceptance tests are conducted on all hardware to determine conformance to design or specifications as a basis for acceptance. Acceptance tests shall be performed on each production article defined by Contract End Item (CEI) specification. The test requirements shall be defined in the CEI and a data package shall be completed by certified quality control inspection, and shall accompany each delivered article. The data package shall include acceptance test data with approval shown by quality control (QC) inspection stamp, and a complete drawing and documentation package.

First Article Inspection (FAI) shall be conducted on the first delivered production article. The FAI data package shall be essentially the same as for acceptance tests. The test shall be conducted by a NASA team assisted, as required, by contractor personnel. Where applicable, completion of FAI shall constitute certification of flight worthiness and manrating. Acceptance tests shall be performed under the surveillance of the applicable NASA Centers or their authorized representatives.

The tests which fall under the category of General Acceptance Tests are as follows:

a. Receiving Tests

b. In Process Tests

   1) Screening Tests

   2) Ambient Tests

   3) Environmental Tests

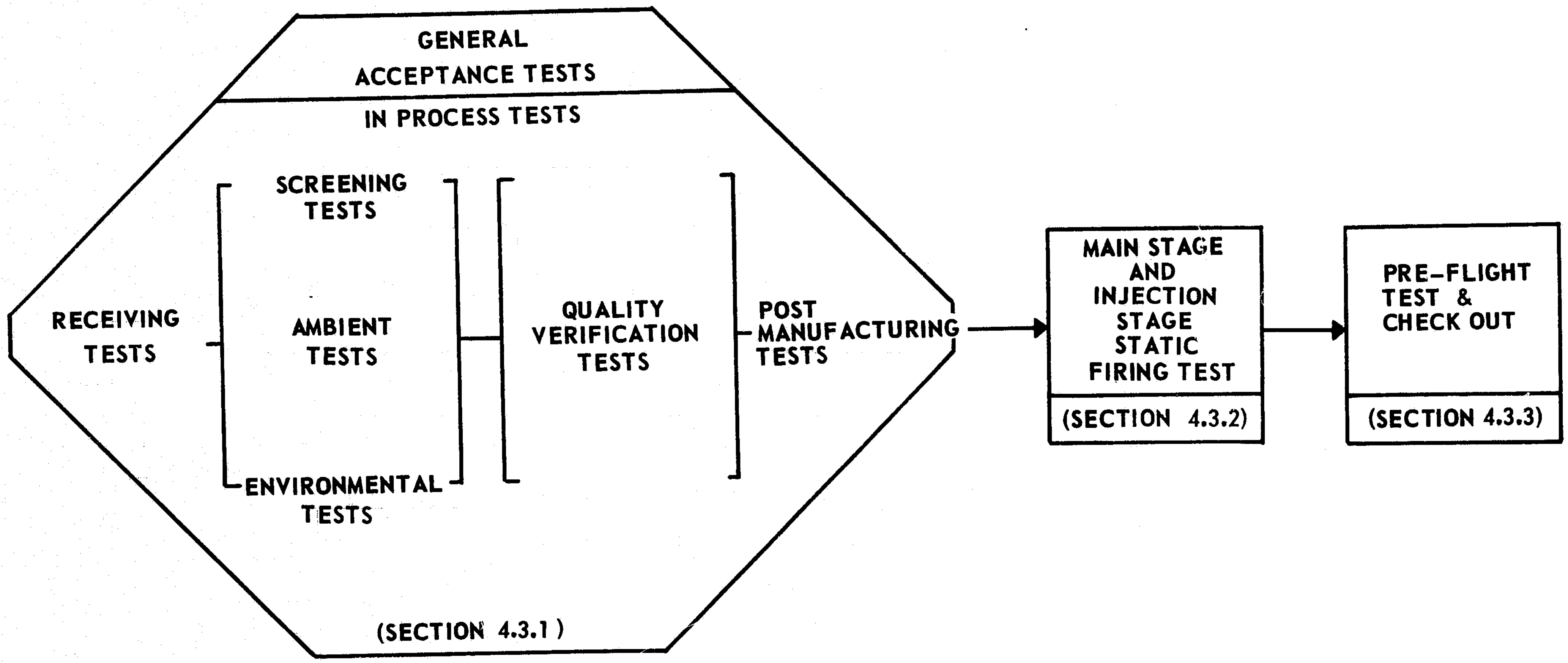

FIGURE 4.3.0.0-1 MANUFACTURING AND OPERATIONS TESTS FUNCTIONAL FLOW

4.3.1 (Continued)

4) Quality Verification Tests

c. Post Manufacturing Test

A general description of these tests and the basis for these tests is presented in the following paragraphs.

Receiving tests are non-destructive, functional tests performed for the purpose of acceptance on piece parts, components, or assemblies on receipt by a manufacturer or a using agency. These tests shall be performed on 100 percent of the functional (operating) items. A receiving test run under other than ambient conditions may also be considered an acceptance environmental test.

In process tests are production tests conducted for the purpose of acceptance and include all tests performed at intermediate points between receiving tests and start of final manufacturing checkout. Principal tests in this category are screening tests, ambient tests, and environmental tests. Description of these tests are shown below:

a. Screening tests are production tests conducted for the purpose of acceptance and are tests employing non-destructive environmental, electrical, or mechanical tests to identify anomalous items. The NASA Center shall establish detailed screening test requirements.

b. Ambient tests are production tests conducted for the purpose of acceptance under ambient environmental conditions such as pressure, temperature, etc., normal for the test location. The NASA Centers shall establish the detailed ambient test requirements.

c. Environmental tests are production tests conducted for the purpose of acceptance under environmental rigors other than ambient for the prime purpose of verifying the quality of the flight hardware or ground equipment. The NASA Centers shall establish the detailed acceptance environmental test requirements. Environmental test levels may be lower than mission environments, provided the NASA Centers determine that such a lower level will reveal all critical quality defects.

In order to guarantee that production items continue to reflect the same quality of workmanship and conformance with design specification that prototype items portrayed, quality verification tests shall be conducted. Selected production items shall be disassembled and inspected in detail for conformance with specification, acceptable workmanship and for potential failure hazards. The findings shall be formally documented and transmitted to the customer.

4.3.1 (Continued)

Post-manufacturing checkout tests are performed for the purpose of acceptance after final assembly at a manufacturer's plant to assure as a minimum that hardware:

a. Was manufactured in accordance with design documents, drawings and specifications,

b. Will function in accordance with design specifications and intent,

c. Will mate physically and functionally with other flight and ground support equipment items.

The successful completion of manufacturing checkout is a prerequisite to assembly into a higher hardware generation level at another contractor's plant or NASA installation, and for shipment to an acceptance static firing or installation site. The requirements of post-manufacturing checkout are similar to those of prelaunch checkout. In fact, the redundant systems with on-board capability can be used directly for post-manufacturing checkout by supplying a properly programmed computer.

4.3.2 Main Stage and Injection Stage Static Firing Tests

Static firing tests of stages and modules for acceptance testing are performed 1) for the purpose of verifying propulsion and control systems integrated performance, and 2) for verifying the capability of all systems to function under the environments generated by the engines operating at full thrust (or variable thrust where applicable)

The need to captive test fire stages is presently justified by the need to develop and qualify the stage/engine combination and the need to develop confidence in the accurate repeatability of the manufacturing and quality assurance methods. The objective of acceptance static firing as stated above, infers that when confidence is established, the tests may be discontinued.

Acceptance test static firing of the main stage and injection stage will be accomplished in the launch stand. The launch facility will be required to withstand the environment imposed by the firing and will include a sonic buffer zone to the nearest populated area. The activity normally accomplished by a launch crew will be very similar to that done by a static test crew. The launch facility was therefore planned to accommodate both the main stage and the injection stage for static firing and refurbishment activities.

A separate acceptance static firing test facility could not be justified as :

a. Acceptance static firing of the completed stage could be discontinued after the first few vehicles are flown.

4.3.2 (Continued)

b. A separate test facility would be expensive not only due to the cost of test stands, but also due to the size of buffer zone required.

c. With the low production rate, a separate test facility would be occupied only half time.

Acceptance firing of stages could be eliminated and replaced by acceptance firing of individual engines or segments of plug nozzles. Test firing of engines is necessary to demonstrate that they operate within specified performance (thrust and I_{sp}). In addition a cold flow test of the stage will be needed to demonstrate equipment operation within specified requirements.

In addition to the expense of land purchase for a separate static firing facility, extensive costs would be incurred for the construction of stands and data acquisition facilities, propellant storage and transport, and transportation and handling stages to and through the test facility.

With the low production rate, not more than two stages would pass through the facility each year. Each S-IC stage (at this time) is at MTF for two months for static firing acceptance testing. Studies conducted by KSC indicated that ten (10) weeks would be required for the same test on the AMLLV core. The studies further indicate that both the core and injection stages can be static fired, refurbished, vehicle stacked, checked out and launched in less than a 30 week period. All this can be accomplished in the launch complex.

4.3.2.1 Static Firing Test Plan

The static firing test activities include the pre-firing test and checkout, the static firing tests, the test and checkout prior to refurbishment, refurbishment and a detailed post-firing checkout. Each liquid propulsive flight stage or module will be subjected to at least one captive firing to verify flight readiness.

Upon receipt at the static firing facility, a stage or module to be tested will undergo an inspection to determine if the configuration is adequate and if any damage has been incurred during transportation from the manufacturing facility. The extent of this inspection shall be determined by the cognizant NASA Center, but as a minimum will be as rigorous as that inspection which the item will receive in premating checkout. Pre-static firing checkout procedures, equipment and test countdown will duplicate, as nearly as practicable, those to be utilized during actual launch.

The flight sequence of events, such as engine, throttling, cut-off and staging will be simulated in the static firing tests. The static firing test measuring program will include all measurements which are to be monitored during actual launch and flight. Since the vehicle flight instrumentation system will be one of the items undergoing test, test measurements will be acquired not only by facility instrumentation systems but by the on-board test and checkout system as well.

4.3.2.1 (Continued)

At the completion of static firing test and prior to maintenance, the tested stage or module shall be thoroughly checked out for structural, electrical, and functional integrity to assure that no system degradation has resulted from the static firing test.

After checkout in accordance with the above paragraph and after maintenance and refurbishment, the tested stage or module will be subjected to a post-static firing checkout which will be equivalent to the post manufacturing checkout. Post-static firing checkouts of stages and modules will be the final acceptance tests performed for the purpose of verifying that the hardware is suitable for launching.

The static test procedures and activities, because of their integral part of the launch activity, are discussed in further detail in the Launch Plan in Section 7.0. The static firing time lines for the main stages and injection stages are shown in Figures 4.3.2.1-1 and 4.3.2.1-2 respectively (see Table 7.3.3.0-I in Section ..0, Launch Plan, for code number breakdown). There will be no acceptance static firing tests for the solid rocket motor stages.

4.3.2.2 Resource Requirements

Use of the launch facility for the static test program means that much of the tooling, equipment and facilities provided for the vehicle launch can be used for the static tests. Use of the launch facility does not, however, negate the requirement for manpower and materials to conduct the tests. Some additional equipment and tooling also will be required such as the positioning and holddown adapters to hold the stages during test. After static test, the launch facility will require refurbishment prior to launch. Refurbishment and post test checkout is also required for the stage or module prior to assembly into the flight configuration.

Six months (26 weeks) is ground ruled for the complete launch cycle, but the time lines for the early flights allow 32 weeks, which can be shortened by paralleling certain operations which are now sequential. The overall time for static firing and refurbishment as illustrated by the combined main stage (M/S) and injection stage (I/S) time lines (Figures 4.3.2.1-1 and -2) is 22 weeks; 69% of the total launch cycle of 32 weeks. Since other launch complex activities are in progress during this time period, only a percentage of the total launch complex manpower is chargeable to this operation. This was estimated to be an average of 48%.

Applying appropriate percentages to the manpower requirements per launch cycle contained in the Launch Plan, Table 7.3.1.0-I, the following Table 4.3.2.2-I was derived. Fuel requirements shown for the injection stage are for the 3 module version, and should be reduced by 1/3 for each wafer removed.

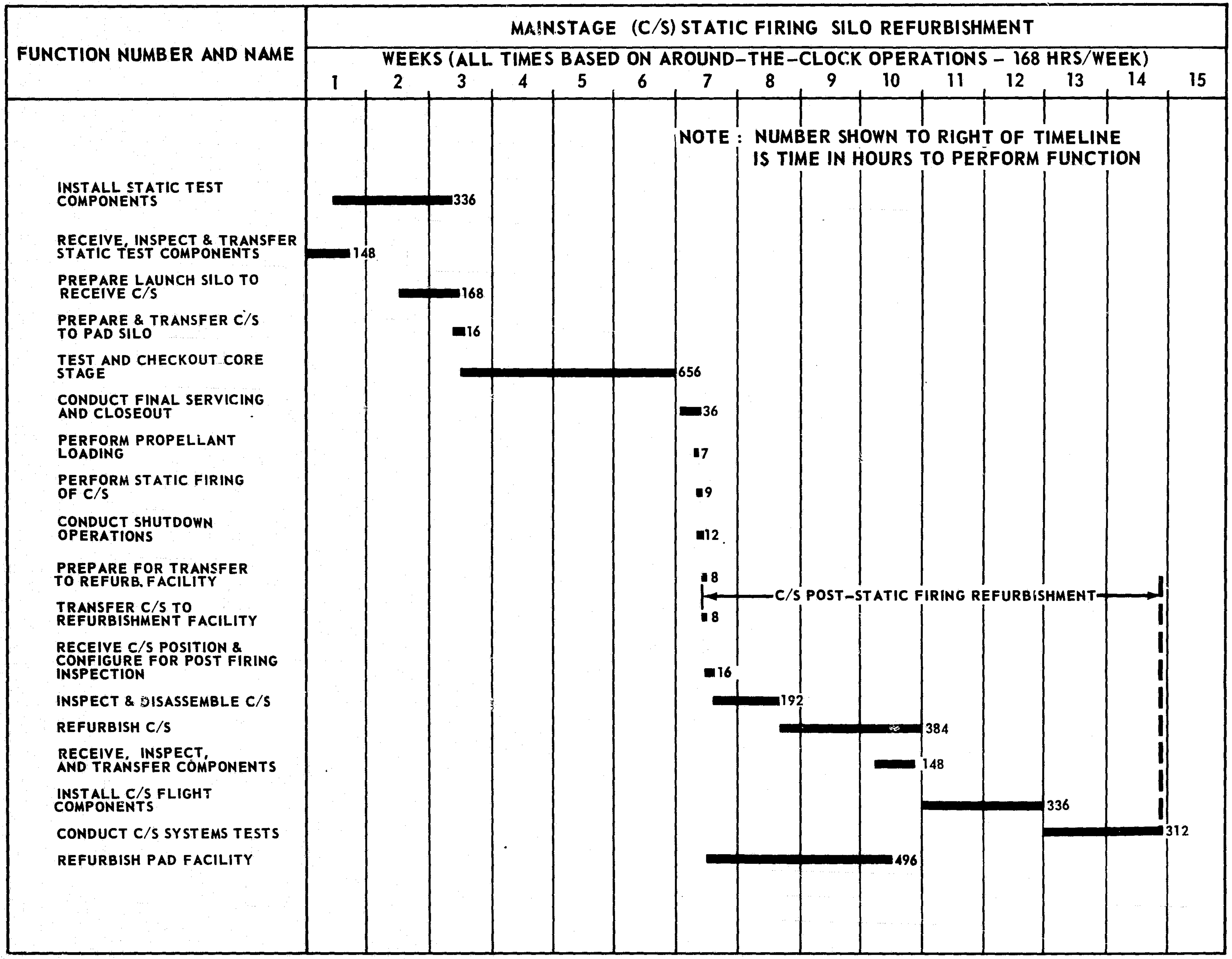

Figure 4.3.2.1-1. MAIN (CORE) STAGE STATIC FIRING & REFURBISHMENT (TIME LINE)

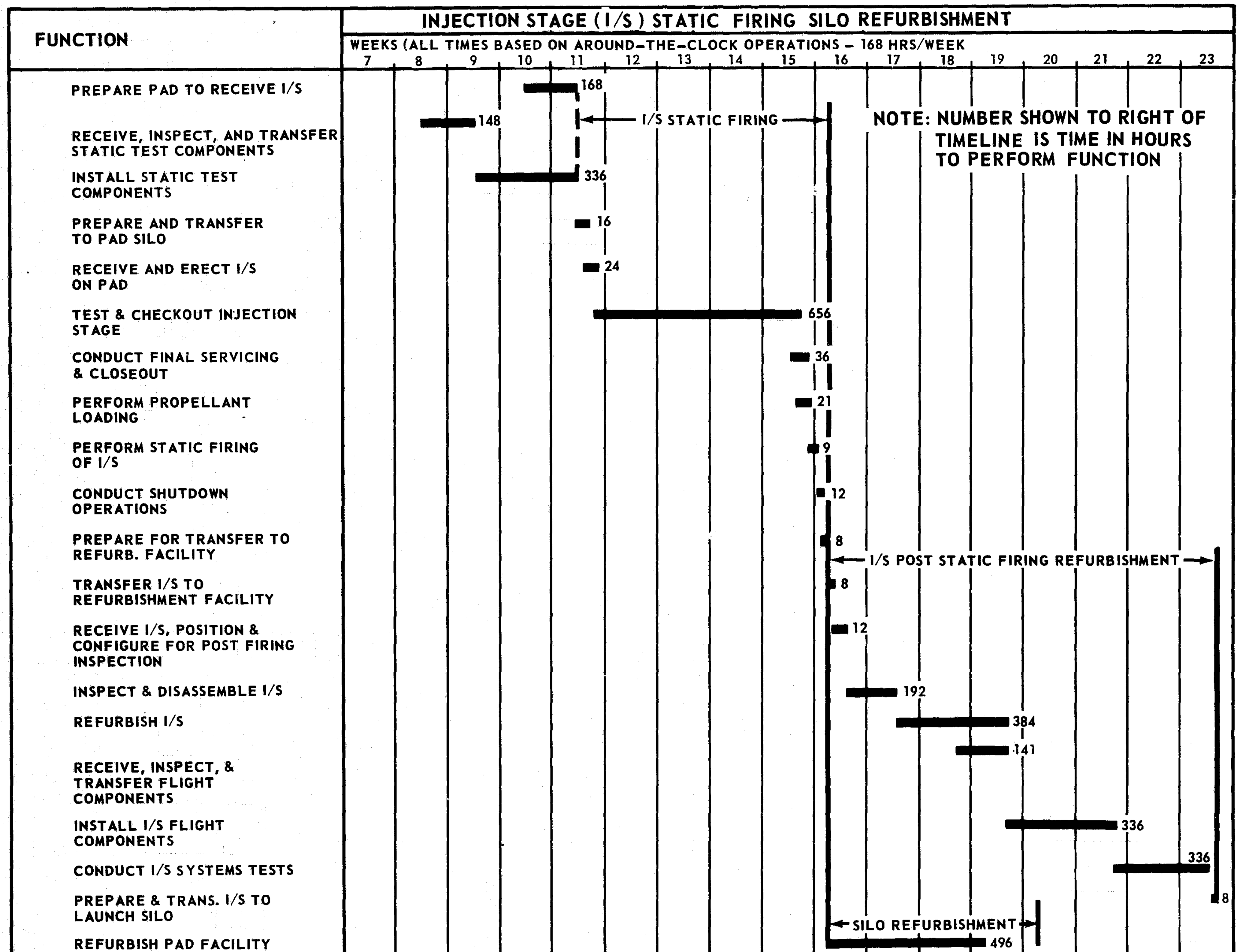

Figure 4.3.2.1-2 INJECTION STAGE STATIC FIRING & REFURBISHMENT (TIME LINE)

TABLE 4.3.2.2-I STATIC FIRING MANPOWER AND FUEL COSTS - AMLLV AND MLLV

	AMLLV	MLLV
Main Stage (M/S)		
Manpower	$27,249,937	$25,711,234
Fuel	$ 1,221,275	$ 610,637
Subtotal M/S	$28,471,212	$26,321,871
Injection Stage (I/S)		
Manpower	$28,590,380	$27,150,667
Fuel	$ 154,550	$ 77,275
Subtotal I/S	$28,744,930	$27,227,942
M/S & I/S Total Manpower	$55,840,317	$52,861,901
M/S & I/S Total Fuel	$ 1,375,825	$ 687,912
Total AMLLV & MLLV	$57,216,142	$53,549,813

4.3.2.2 (Continued)

The manhours required for static firing an injection stage with one, two or three modules will not vary significantly. Each stage to be static fired will arrive at the launch complex completely assembled and checked out prior to leaving the manufacturing facility. Handling and firing time would be the same, with a little longer required to fuel up added I/S modules. Checkout time would vary according to the number of engines, with the possibility also of some increase in refurbishment time for the greater number of engines.

Table 4.3.2.2-I tabulates the manhours and fuel costs for the M/S and I/S for both the AMLLV and half size MLLV for static firing, refurbishment and checkout. It is indicative of the resources in time and money to be saved once the need for static firing each flight stage has been eliminated. The goal of two launches per year will be met more readily, with an annual saving of well over $50,000,000.

4.3.3 SRM Stage Subsystem/System Tests

In-plant tests of completed subsystems and/or major components will include:

a. Stage Sequencing System Test

   Verify operation of stage sequence and control distributor function relays by sending programmed coded signals from the computer.

b. Stage Instrumentation System Channel Identification Test

   Verify operation of stage telemetry system to assure that each channel has only the assigned function.

c. Range Safety System Test

   Verify generation of arming, engine cutoff, and SRM destruct signals by transmitting open or closed loop RF commands to the stage range safety command receivers.

d. Simulation Flight Test

   Verify operational readiness and mutual compatibility of stage and SRM systems for launch and flight.

e. Commanded Premature SRM Separation System Test

   Verify the presence of separation, and destruct signals only when the proper combinations of malfunction signals (as generated by the computer) are received from the computer.

4.3.3 (Continued)

f. Stage Electrical Connections Test

Perform quality/acceptance tests to prove proper separation of electrical connectors occurs on SRM staging.

g. Separation System Test

Verify the presence of an acceptable SRM separation firing signal when the separation firing system is actuated.

h. Stage Power Systems Test

Verify the presence of stage DC power at SRM connection points when the proper signals are generated.

i. 260-Inch Case Pressure Test

Perform a hydro test of the solid motor case to prove capability to withstand pressures encountered during launch and flight operations.

j. Solid Motor Thrust Vector Control (TVC) System Test

Perform a test of the TVC system to determine electrical and hydraulic system functional operation. Calibrate the TVC deflection angle and response rate to the input signals.

These tests will also be repeated at the receiving and inspection dock at KSC to assure functionality (after transportation) prior to assembly of the solid stage to the core vehicle.

4.3.4 Pre-Launch Checkout of Space Vehicles

The primary objective of the pre-launch checkout is to determine that the assembled space vehicle is ready for launch. NASA shall publish a pre-launch checkout plan for each space vehicle. Approximate inputs to the plan will be provided by subordinate contractors. The plan shall include as a minimum:

a. Pre-launch checkout operations to be conducted on stages, modules, and the space vehicle to verify readiness for launch.

b. Overall sequence and schedule for accomplishing space vehicle checkout operations.

c. NASA and contractor responsibilities and relationships and contractor controls.

4.3.4 (Continued)

d. Working level test documentation and records requirements.

4.3.4.1 Prelaunch Test and Checkout Plan

The prelaunch checkout will include the following as a minimum:

a. Visual inspections to assure satisfactory physical condition.

b. Functional checkout and compatibility verification of all subsystems within the space vehicle not confined within a stage or module. Includes verification of instrumentation calibrations.

c. Electromagnetic interference test: First operational vehicle.

d. Simulated flight.

As this activity is integral with the Launch Plan, it is discussed in more detail in Section 7.0.

4.3.4.2 Resources Implications

The following paragraphs describe the resource requirements for the prelaunch test and checkout of the vehicle.

Launch Facilities and Equipment - Test

The launch complex will require equipment which can be broken down into two major categories as follows:

a. Facility ground support equipment - GSE

b. Stage peculiar ground support equipment - LVGSE

Equipment falling under categories "a" and "b" was priced based on lists provided by BATC.

The following is a summary of the type of equipment required for prelaunch test and checkout activities.

Facility Ground Support Equipment (GSE)

a. Propellant, tanking computer.

b. Wideband transmission system.

4.3.4.2 (Continued)

c. Operational TV system.

d. Abort advisory.

e. Operational intercom system.

f. Photo optical system.

g. Launch data system.

h. Facility systems control and display.

i. Hazardous gas detection system.

j. Facility command and control computer.

k. Instrumentation data display system.

l. Facility monitoring system.

m. Central instrumentation T/M system.

n. Count clock.

o. Ground equipment test set.

<u>Stage-Peculiar Ground Support Equipment (LVGSE)</u>

a. Test and checkout computer.

b. Terminal countdown sequencer.

c. Launch vehicle control and display.

d. Launch vehicle command and control computer.

e. Launch vehicle monitoring system.

<u>Required Test GSE - SRM Stage</u>

The ground support equipment required to support the processing of the SRM at the launch site is listed below.

4.3.4.2 (Continued)

a. Electronic checkout van.

b. Hydraulic power servicing unit.

c. Motor leakage pressurization unit.

d. Leak detection unit, helium type.

e. Pneumatic power supply cart.

f. Nozzle/TVC alignment kit.

g. Maintenance stands.

Manpower and Material Costing

Because the testing at launch site will include static firing of powered stages, and test and checkout of the assembled vehicle in the launch mode, all ground support equipment will be required along with the special test support equipment. This also includes transportation and handling equipment. See Section 7.0, Launch Plan, for manpower and material costs.

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5.0 MANUFACTURING PLAN

This manufacturing plan presents the fabrication and assembly methods for the main stage, injection stage and solid-rocket motor stages of the AMLLV and MLLV vehicle configurations. The plans are, where practical, an extrapolation of fabrication techniques developed for the Saturn V/S-IC booster stage. By making use of the plans, processes and tooling concepts for this stage, program costs for the fabrication of the flight stages will be minimized. Differing manufacturing techniques are incorporated into the plan where advantageous.

This plan was written for the MLLV family. The similarity of the MLLV and AMLLV makes it possible to apply the same plan to the AMLLV family. Where differences do exist, the AMLLV data is shown enclosed in brackets following the MLLV data. In some instances, where the data is complex, a separate subparagraph has been prepared.

The manufacturing plans include a description of each stage, a detailed fabrication and assembly plan for each stage, and the resources required to fabricate the stage.

The main stage, injection stage and SRM stages of the MLLV are described in detail in Volume II of this final report on contract NAS2-5056, "Cost Studies of the Multipurpose Large Launch Vehicle." The main stage, injection stage and SRM stages of the AMLLV are described in detail in Boeing Document D5-13421-2, Volume II of the final report on contract NAS2-4079, "Study of Advanced Multipurpose Large Launch Vehicles". Brief descriptions of these main stages are presented below:

The main stages of the MLLV and the AMLLV will be all aluminum structures using the technology developed on the Saturn V/S-IC. The MLLV main stage will be 56.7 feet in diameter and 138 feet tall. The AMLLV main stage will be 71.7 feet in diameter and 158 feet tall. Both structures will consist of the following major subassemblies:

a. Forward skirt;
b. LOX tank;
c. LH_2 tank;
d. Aft skirt;
e. Centerbody plug;
f. Subsystems such as the propulsion/mechanical, electrical/electronic, etc.

The forward skirt will be an aluminum (7075-T6) mechanically fastened, skin-stringer-frame structure. It will be composed of skin panel subassemblies, an intermediate ring frame, a deep ring frame to react holddown loads and a forward interface angle-ring for forward attachment to the payload or to the injection stage.

The LOX and LH_2 propellant tank will be welded aluminum structures, employing welded T-stiffeners in the cylindrical sections. They will be composed of upper and lower elliptical bulkheads welded from bulge formed gores and an insulated honeycomb semi-elliptical common bulkhead. LH_2 will be contained between the common bulkhead and

5.0 (Continued)

the lower bulkhead, and LOX above. An anti-vortex cruciform baffle will be located inside the common bulkhead. Cantilever ring baffle assemblies will extend inward from the common fitting of the common bulkhead and the junction ring fitting of the lower bulkhead.

Twenty-four LOX tunnels will feed through the LH_2 tank from a LOX duct manifold fitting in the center of the common bulkhead and will penetrate the LH_2 tank lower bulkhead near the side wall in the vicenity of each engine. These tunnels will be tied together inside the LH_2 tank and braced with high strength tension rods attached to collars which surround each tunnel. LH_2 feed lines will emanate from a fitting in the bottom center of the lower bulkhead and will extend radially inside the LH_2 tank penetrating it near each engine. (If the toroidal/aerospike propulsion system is used only eight feed lines are required.)

The aft skirt section will be a mechanically fastened assembly consisting of skin panel subassemblies, thrust posts, intermediate ring segments, thrust ring segments, inner splice plates, centerbody-plug post-attach fittings, and oxidizer fuel pressurization manifolds with their respective attach fittings. Each of the skin panel subassemblies will be a single preformed (7075-T6) aluminum sheet. Twenty hat sections extending the full length of the panel will be mechanically fastened to each skin panel. Each hat section will be reinforced with outer splice plates at the upper end of the skin panel to provide additional strength at the lower bulkhead Y-ring attach points. An inner splice plate will also be used in final assembly to provide an interface surface between the rear of the lower bulkhead Y-ring and the skin panel inner surface. The intermediate ring will be assembled in the final assembly fixture using the preformed segments. Each segment will be mechanically fastened to the inner side of the thrust posts. The lower thrust ring assembly will form the base of the aft skirt structure when its ring segments are positioned and joined in the major assembly fixture. Both the intermediate and thrust ring segments will be constructed of inner and outer rolled aluminum T-chords. The bonded honeycomb web segments will be mechanically fastened to the inner and outer caps.

The centerbody plug will be a conic structure with a base consisting of a stringer-sheet bulkhead. Two major assemblies will make up the structure; the base plug (conic section structure) and the base bulkhead. The base plug will be an aluminum honeycomb core structure with stainless steel as inner and outer face sheets. LH_2 cooled tubes (monel) will be brazed to the outer face of the honeycomb structure. The tubes will fit into upper and lower manifolds of the base plug. The lower manifold of the base plug will mate with the aluminum (2219-T87) stringer-sheet base bulkhead. These two structures will be mechanically fastened to form the complete centerbody plug.

Final assembly operation will consist of mating the major structural assemblies to the core stage configuration and installing the propulsion and electrical system components on the stage. The structural assemblies, with the exception of the centerbody plug and engines, will be assembled with the stage in a vertical position. All other systems installations will be accomplished horizontally.

5.0 (Continued)

The propulsion/mechanical systems used in the main stage are the propellant feed systems, pressurization systems, engine control, destruct ordnance, environmental control, ordnance and control pressure. The functions of each of these systems, fabrication and assembly procedures and necessary resources were identified. For the electrical/electronic system; the electrical power and network system, data systems, communication and tracking system, command destruct system and the guidance and control system, the functions, fabrication and assembly procedures and necessary resources were identified.

The main stage resources were collected in terms of the following:

a. Manpower to fabricate the assemblies and subassemblies;

b. Materials costs based on extrapolation of S-IC material costs to the AMLLV and MLLV configurations;

c. Tooling costs by major subassemblies;

d. Capital equipment grouped by assembly and subassembly;

e. Facilities categorized by manufacturing and test requirements.

A summary of the resources data is shown in Table 5.0.0.0-I. Detail backup is shown in Paragraph 5.2. Manhours were converted to dollars for this table when necessary to add to dollars.

TABLE 5.0.0.0-I SUMMARY OF RESOURCES INPUTS FOR THE MAIN STAGE

Item		AMLLV	MLLV
Manpower	(Direct Recurring)	2,473,364 m/h	2,096,363 m/h
	(Direct Nonrecurring)	23,620,245 m/h	16,801,646 m/h
Material Costs	(Structure-Recurring)	$ 4,931,613	$ 2,631,000
	(Systems-Recurring)	$ 28,173,000	$ 25,356,000
	(MGSE-Nonrecurring)	$ 8,363,000	$ 5,269,000
	(Tooling-Nonrecurring)	$ 19,054,000	$ 11,557,000
*Tooling Costs (1)	(Nonrecurring)	$ 90,505,000	$ 87,405,000
	(Recurring)	$ 3,704,000	$ 3,563,000
*Facilities Costs	(Nonrecurring)	$151,105,000	$136,575,000
	(Recurring)	$ $7,916,000	$ $7,572,000

*Tooling and Facility costs are for both the main stage and injection stage. These stages are manufactured in the same facility and use some of the same tools.

(1) Tooling costs are for labor and material.

5.0 (Continued)

The injection stage will be all aluminum structures consisting of from one to three cylindrical modules of skin-stringer-frame construction. For the AMLLV configurations, each injection stage module will be 71.7 feet in diameter and 18.3 feet long. For the MLLV configurations, each injection stage module will be 56.7 feet in diameter and 15 feet long. Each module will contain two toroidal propellant tanks (LOX tank and LH_2 tank). The upper tanks will drain their fuel into the corresponding fuel tank of the lower module. The upper modules are fuel modules only. The lower module in addition to the fuel tanks, will contain the thrust structure, heat shield and all engines for the injection stage. Two engines will be mounted in the lower module for each module used on the injection stage.

The cylindrical skin structure of each module will be similar to the forward skirt of the main stage and will be constructed of 7075-T6 aluminum skin panel subassemblies. The modules will be connected by a shear pin connection at the ring frames located at the top and bottom of each stage.

The torus LOX and LH_2 fuel tanks will be fabricated from 2219-T87 aluminum. The LH_2 tank will be connected to the skin structure by shear pins. The LOX tank will be mounted within the inner diameter of the LH_2 tank. A fiberglass hanger strap will connect the two assemblies. The upper end of the strap will be shear-pin connected to the outer diameter of the LOX tank. Eight web panel assemblies of a sandwich aluminum honeycomb structure spaced 45 degrees apart will provide torsional rigidity.

The tanks will be connected by a stainless steel convolute bolted into the aluminum tanks. A teflon outer convolute will act as an insulator for the inner convolute and will be coated with a spray-on type polyurethane. Propellants will drain from the upper tanks into the lower tanks during injection stage thrusting; therefore, residuals in the upper tanks will be negligible by thrust termination. Toroidal manifolds, attached to the lower module, will effectively drain the tanks. Float valves will ensure manifold suction of liquids and hot gases no matter what position the tank assumes. All the engines will be flex-joint connected to the manifolds, which are sized to feed all size engines with only one float valve open in each manifold.

The thrust structure in the lower injection stage module will consist of two thrust rings and six engine-mount forgings (thrust posts). The engine mounts will be pin-connected at the ends to the engines. The engines will be mounted on cantilever forgings from two (moment-restraining) ring frames. Additional engines will be added around the ring frames as additional modules are added. The extendable nozzle engines will be nested into the forward skirt area of the main stage to save stage length. They will extend their nozzle and gimbal outward after main stage and injection stage separation.

The engine design used in evaluating the injection stage performance was the high chamber-pressure, translating nozzle concept as defined by Pratt and Whitney. This engine will use liquid hydrogen and liquid oxygen propellants. The translating nozzle will provide a means of minimizing the engine installation envelope. The major portion of the nozzle will be dumped cooled. The engine will use a preburner cycle.

5.0 (Continued)

The resources for the injection stage were collected employing the same resources criteria as was used for the main stage. The categories were manpower to fabricate, materials, capital equipment, and facilities. A summary of the injection stage resources data is shown in Table 5.0.0.0-II. Detail backup data is contained in Paragraph 5.3.

The solid-rocket motor stage (SRM) used for the AMLLV and MLLV will be 260-inch (in diameter) solid-propellant rocket motors converted into stages for the AMLLV and MLLV vehicle applications. For the AMLLV, twelve 260-inch SRM's will be used. For the MLLV, eight 260-inch SRM's will be used. The solid-propellant motor will consist of a case, propellant, nozzle, ignition system, thrust vector control system and a destruct system. The solid motor will be converted into a stage by the addition of on-board power sources, flight instrumentation, forward and aft skirts, attachment fittings, nose cone and a separation system. The AMLLV SRM stage will contain 3.8 million pounds of propellant; the MLLV SRM stage will contain 2.9 million pounds of propellant.

The motor case will be fabricated from 18 percent maraging steel. The case will consist of a cylindrical section 260 inches in diameter. Y-rings at each end of the cylindrical section will join it to hemispherical forward and aft closures and to the forward and aft SRM skirts. The forward closure will contain a 28-inch opening for the igniter. The aft closure will contain a 180-inch opening for the nozzle assembly. The nozzle assembly will consist of a maraging steel shell with an ablative insulation liner. The shell will extend to a point just aft of the nozzle throat. From that point to the start of the exit cone, 4130 steel will be used with an ablative insulation liner. The exit cone will be aluminum honeycomb core covered externally with fiberglass cloth and internally with an ablative liner. Thrust vector control will be provided by a flexible seal system. The actuation force will be applied by a hydraulic actuator mounted between the aft closure and the nozzle shell.

The propellant will be a composite PBAN type propellant. After the case is cleaned, lined and insulated, a mandrel will be placed into the motor. The propellant will be cast and cured to the configuration provided by the mandrel. After cure, the mandrel will be removed and the nozzle assembly attached.

The strap-on stage components will consist of an onboard power source, a flight instrumentation system, a separation system, solid-motor attachment fixtures and a solid-motor nose cone. The on-board power system, flight instrumentation and the separation system will be fabricated or procured by the solid-motor contractor and installed on the solid motor at the fabrication site. The forward and aft attachment fittings and the nose cone will be fabricated at Michoud and shipped to the solid-motor fabrication site for assembly to the solid-motor stage.

The SRM forward attachment structure will be a cylinder 260 inches in diameter constructed of HY-140 steel. It will be a skin-stringer-frame construction. The skin will consist of 14 sections welded together to form a 260-inch diameter cylinder. One of the sections will incorporate a forged ignition fitting and an igniter safety and arming device fitting.

TABLE 5.0.0.0-II SUMMARY OF RESOURCES INPUT FOR THE INJECTION STAGE

Item	AMLLV (No. of Modules)			MLLV (No. of Modules)		
	1	2	3	1	2	3
Manpower Hours (Direct-Recurring)	486,000	800,000	1,114,000	383,000	614,000	884,000
(Direct-Nonrecurring)	4,750,000			3,125,000		
Materials Cost (Structures-Recurring)	$ 847,000	$ 1,388,000	$1,929,000	$ 440,000	$ 723,000	$ 926,000
(Systems-Recurring)	$ 1,200,000	$ 1,799,000	$2,398,000	$1,080,000	$ 1,645,000	$2,209,000
**(MGSE-Nonrecurring)	$1,004,000			$1,004,000		
**(Tooling-Nonrecurring)	$5,042,000			$3,177,000		
Tooling Cost	*			*		
Facilities Cost	*			*		

*Tooling and Facilities costs shown in Table 5.0.0.0-I include both the main stage and injection stage tooling and facility costs

**MGSE and tooling for the engine (#1) module of the injection stage are also used for the fuel modules.

5.0 (Continued)

The SRM thrust (shear) post will be fabricated from HY-140 and will be MIG-welded to the skin. The post will have a cross shape. A steel sleeve will be welded to the thrust post at the intersection of the cross. This sleeve will mate the SRM to the main stage sleeve.

The skin of the forward attachment structure will have a forward thrust ring mounted at the head end. At the aft end, an aft skin ring and an aft thrust structure will be welded to each other, and then in turn to the skin forward thrust ring assembly. Four intermediate rings will then be mechanically fastened to the subassembly. Longitudinal stiffeners will then be installed.

The aft attachment structure will be cylindrical in shape and fabricated from HY-140 steel structure with longitudinal stringers (similar to the forward attachment structure) welded to the external skin surface. The skin will be supported on the inside with six reinforcing rings and two support posts. The cylindrical skin-ring will be fabricated from 20 skin sections. Two of these skins will incorporate fairings to house the lower SRM staging rockets. Each of the two vertical support posts will be comprised of two welded and machined forgings. The reinforcing rings will be attached and the longitudinal stiffeners welded in the same manner as described for the forward attachment structure.

The aft attachment fittings will consist of two tubular support struts and a side-load fitting. The tubular support struts will extend between the SRM attach lugs and the attachment fittings mounted on the core stage. The struts and the attachments on the core will be 7075-T6 aluminum. The SRM fittings will be HY-140 steel. Both ends of the struts will contain spherical bearings. One end will be pinned to the SRM attachment lug; the other end will be pinned to the core lug.

The side-load fitting located in the SRM stage will mate with a slip-load fitting welded to the core stage. The slip-load fitting will be fabricated from die forged 7075-T6 aluminum. The spherical ball mounted in the side-load fitting will ride in the channel of the slip-load fitting.

The solid-motor nose cone will be a conical 7075-T6 aluminum alloy structure. The cone will be reinforced on the inside with 40 Z-section stringers and five rings. The skin will consist of two skin-ring sections and a nose fairing assembly. The center skin section will also have the staging-rocket fairing mechanically fastened to the skin. The staging rocket will be supported by bracketry on the cone interior. The entire exterior of the cone will be covered with an ablative coating.

The resources for the solid-propellant motor costs were obtained from Aerojet-General. Resources for the forward and aft attachment structures, the nose cone and the attachment fittings costs were obtained from Boeing-Michoud. A summary of the resource implication data obtained for the SRM stage are shown in Tables 5.0.0.0-III and -IV and in more detail in Paragraph 5.4.

5.0 (Continued)

TABLE 5.0.0.0-III SUMMARY OF RESOURCES INPUT FOR THE SRM STAGE (SOLID MOTOR DATA PROVIDED BY AEROJET)

	AMLLV	MLLV
Tooling (Nonrecurring)	$ 58,801,000	$41,941,000
Facilities (nonrecurring)	67,667,000	45,100,000
Total (nonrecurring)	$126,468,000	$87,041,000
Solid Motor (Recurring	$ 7,725,000	$ 6,102,000

TABLE 5.0.0.0-IV SUMMARY OF RESOURCES INPUT FOR THE SRM STAGE (NOSE CONE, FORWARD AND AFT ATTACH STRUCTURE AND FITTINGS - DATA PROVIDED BY BOEING MICHOUD

Nonrecurring	AMLLV	MLLV
Tooling Materials	$ 1,917,000	$ 1,848,000
GSE Materials	762,000	762,000
Facilities	3,230,000	3,230,000
Equipment	2,494,000	2,274,000
Development Test	139,987,000	120,170,000
Total Nonrecurring Dollars	$148,390,000	$128,284,000
Tooling Manhours (Nonrecurring)	1,096,000	1,056,000
Recurring	AMLLV	MLLV
Materials	$ 1,218,000	$ 1,115,300
Facilities	208,000	202,000
Total Recurring Dollars	$ 1,426,000	$ 1,317,300
Manufacturing Manhours (Recurring)	301,168	247,000

5.1 GUIDELINES AND ASSUMPTIONS

This plan is based on the MLLV design configuration presented in Volume II of this final report on; Cost Studies of the Multipurpose Large Launch Vehicles - Half Size (MLLV) Design, and NASA Document CR73154, Study of Advanced Multipurpose Large Launch Vehicles - Technical Report. It was developed according to the following guidelines and assumptions:

a. Production rate of two vehicles per year;

b. Saturn V/S-IC plans, processes, and tooling will be used for producing MLLV (AMLLV) hardware wherever possible;

c. All tasks are planned on the basis of a two-shift, forty-hour work week;

d. The plan is based on LOX cleaning, for which techniques and processes have previously been developed;

e. All subsystems functional and acceptance testing will be performed by the vendor except as noted;

f. No provisions have been made for spares;

g. Make-or-buy determinations will be in consonance with precedents established by the Saturn program;

h. Additional research and development will be required;

i. Systems installation will be accomplished in the horizontal and vertical assembly positions, as dictated by accessibility and installation requirements;

j. Main stage engines will be installed with the vehicle in the horizontal position.

5.2 MAIN STAGE MANUFACTURING PLAN

The Manufacturing Plan shown below is applicable to both the AMLLV and MLLV. The AMLLV data has been shown in parenthesis next to the MLLV data.

The MLLV (AMLLV) main stage is of a cylindrical, tandem tank configuration, approximately 56.7 (72) feet in diameter and 138 (158) feet high, Figure 5.2.0.0-I. The propellant tanks are separated by a common bulkhead. The lower tank contains LH_2, while the upper tank contains the oxidizer, LOX.

Twenty-four LOX tunnels originate at the bottom (center) of this tank, and extend radially downward through the LH_2 tank penetrating the LH_2 tank bulkhead. LH_2 ducts radiate from an inlet fitting in the bottom of the LH_2 tank and also penetrate the LH_2 bulkhead near the edge. The propellant and oxidizer lines are connected to twenty-four engines that are mounted circumferentially near the base of the vehicle.

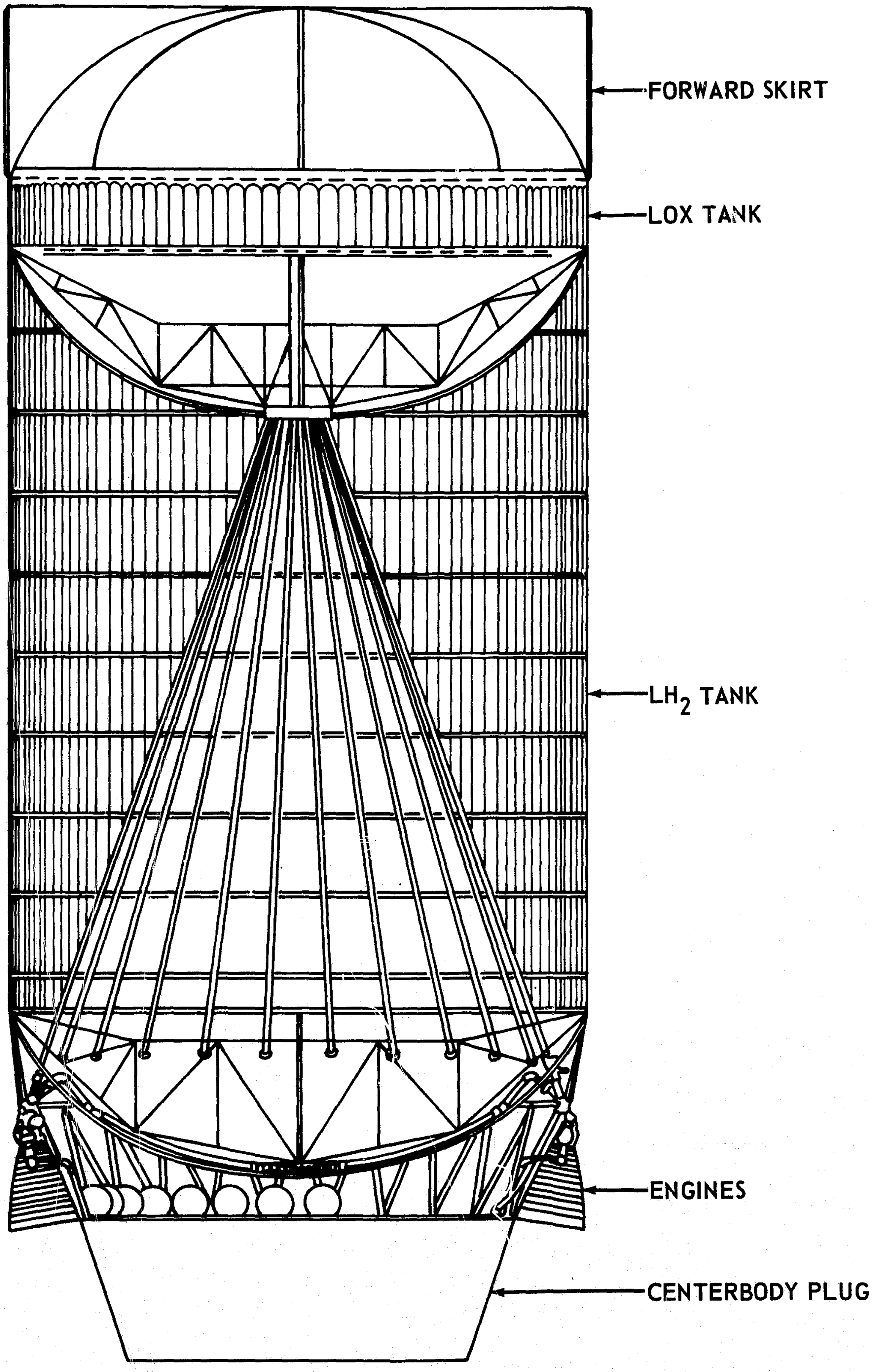


FIGURE 5.2.0.0-1 CORE STAGE - AMLLV/MLLV

5.2 (Continued)

The main stage is constructed from 2219-T87 and 7075-T6 aluminum alloys. The propellant tanks are made from 2219-T87 aluminum fusion welded into a cylindrical shape. The forward and aft skirt sections are fabricated using 7075-T6 aluminum. These sections are mechanically attached to the propellant tank assembly. The tubular truss work is constructed as an integrated assembly and mechanically joins the aft skirt and centerbody plug assemblies of the stage.

The main stage of the MLLV (AMLLV) is composed of the following major assemblies:

a. Forward skirt assembly;
b. Propellant tank assembly;
c. Aft skirt assembly;
d. Centerbody plug assembly;
e. Propulsion system and accessories;
f. Instrumentation and electrical components.

The fabrication, assembly sequences, and tooling for each structural assembly, a. through d. above, are presented in this section. Upon final assembly, these structures are mated and the instrumentation, electrical components and propulsion systems are installed.

5.2.1 Forward Skirt Fabrication and Assembly Procedure (Heavy Weight)

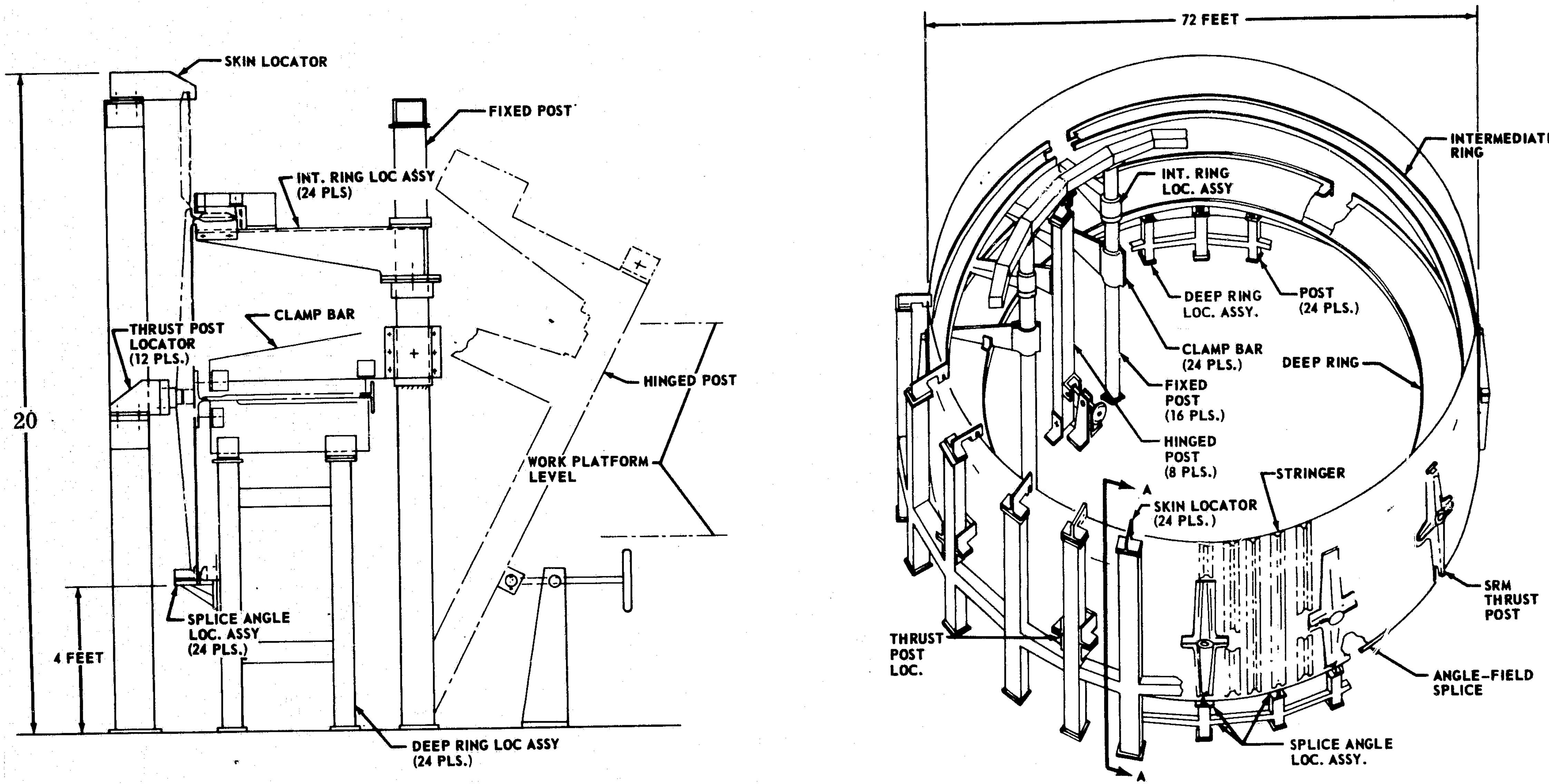
The forward skirt is an aluminum (7075-T6) mechanically fastened, skin-stringer-frame structure. It is composed of eight (12) skin panel subassemblies, an intermediate ring frame, a forward interface angle ring for forward attachment and a deep ring frame. This deep ring frame reacts solid-motor stage thrust loads.

Each skin panel subassembly is fabricated from cylindrical skin segments and hat section stiffeners. When SRM stages are used, a thrust post is located at the vertical centerline of each of the eight (12) panels.

Both intermediate and deep ring frames are comprised of a bonded honeycomb web mechanically fastened to inner and outer T-chords. The deep frame is about 60 (87) inches from the inner to the outer diameter, while the intermediate frame has a corresponding dimension of 20 (25) inches. These frames are built up from eight (12) rolled arcs mechanically fastened to form a ring. This ring, like the ring frames, is assembled in place on the major assembly fixture, Figure 5.2.1.0-1.

5.2.1.1 Forward Skirt Subassemblies (Heavy Weight)

Skin Panels — Forward, center, and aft skins are trimmed from flat sheets and rolled to the proper curvature. Hat sections are cut to length from aluminum extrusions and hot-joggled on a press at each end to permit attachment to the LOX tank Y-ring forward flange and the forward angle-ring. The holddown posts are rough machined from a forged block, heat treated, and machine finished. Machining is accomplished on a



A-A

FIGURE 5.2.1.0-1 FORWARD SKIRT ASSEMBLY FIXTURE (AMLLV)

numerically controlled mill. All detail parts are degreased, alkaline cleaned, alodined, and primed prior to assembly.

The forward, center, and aft skins are then loaded into the skin panel subassembly fixture, Figure 5.2.1.1-1, along with the formed hat section stringers and holddown or thrust fitting. Parts and drill plates are clamped into position and approximately 10,000 attach holes are drilled with automatically fed pneumatic drills. Parts are then removed from the fixture and deburred, then loaded into the fixture and fastened. Fastener heads are touched-up with primer, and the completed assembly is removed and stored for subsequent use. Figure 5.2.1.1-2 depicts the skin panel assembly sequence.

Intermediate and Deep Ring Frame Segments — Ring-frame, web-face sheets and unformed Z-section flat strips are cut to size. The face sheets are loaded into a track router fixture, similar to that shown in Figure 5.2.1.1-3, and trimmed net. The Z-section strips are rolled to the Z-shape and subsequently rolled to curvature. The Z-sections are then sawed to length and trimmed net. Face sheets and Z-sections are deburred, alkaline cleaned, rinsed, cleaned in a hot deoxidizing solution, rerinsed, and dried. Surfaces to be bonded are sprayed with an adhesive primer. The adhesive film is applied to these surfaces just prior to bonding.

Honeycomb cores are placed on a track router fixture equipped with a combination polyglycol/vacuum chuck, Figure 5.2.1.1-3, profiled to net size, and chamfered. The honeycomb is stabilized on the edges with solidified polyglycol during machining. The polyglycol is then rinsed from the honeycomb with hot water, and the honeycomb cores are degreased and dried.

Z-sections, face sheets and honeycomb core are placed into the ring segment bonding fixture. A vacuum bag is placed over the assembly to apply even pressure to the face sheets. The entire assembly is moved into an autoclave for the curing cycle. When pressure is reached on the outer surface of the assembly, the vacuum side is vented to the atmosphere. When the adhesive has cured, the fixture is removed and the part cooled. The web assembly is then conversion coated and spray primed.

The inner and outer T-chords are made from extruded T-sections which have been rolled to contour and rough machined on a boring mill. The sections are heat treated, reinstalled on the mill, and machine finished. They are then degreased, cleaned, conversion coated, and spray primed.

The inner and outer chords, bonded web assembly, and drill plates are placed into a ring segment subassembly fixture, Figures 5.2.1.1-4 and 5.2.1.1-5, and clamped in place. Fastener holes are drilled, then the parts are removed, deburred, and replaced in the fixture. All fasteners are installed which join the inner and outer chords to the web assembly. Rivet heads are then touched-up with primer.

Figure 5.2.1.1-6 illustrates the above assembly sequence.

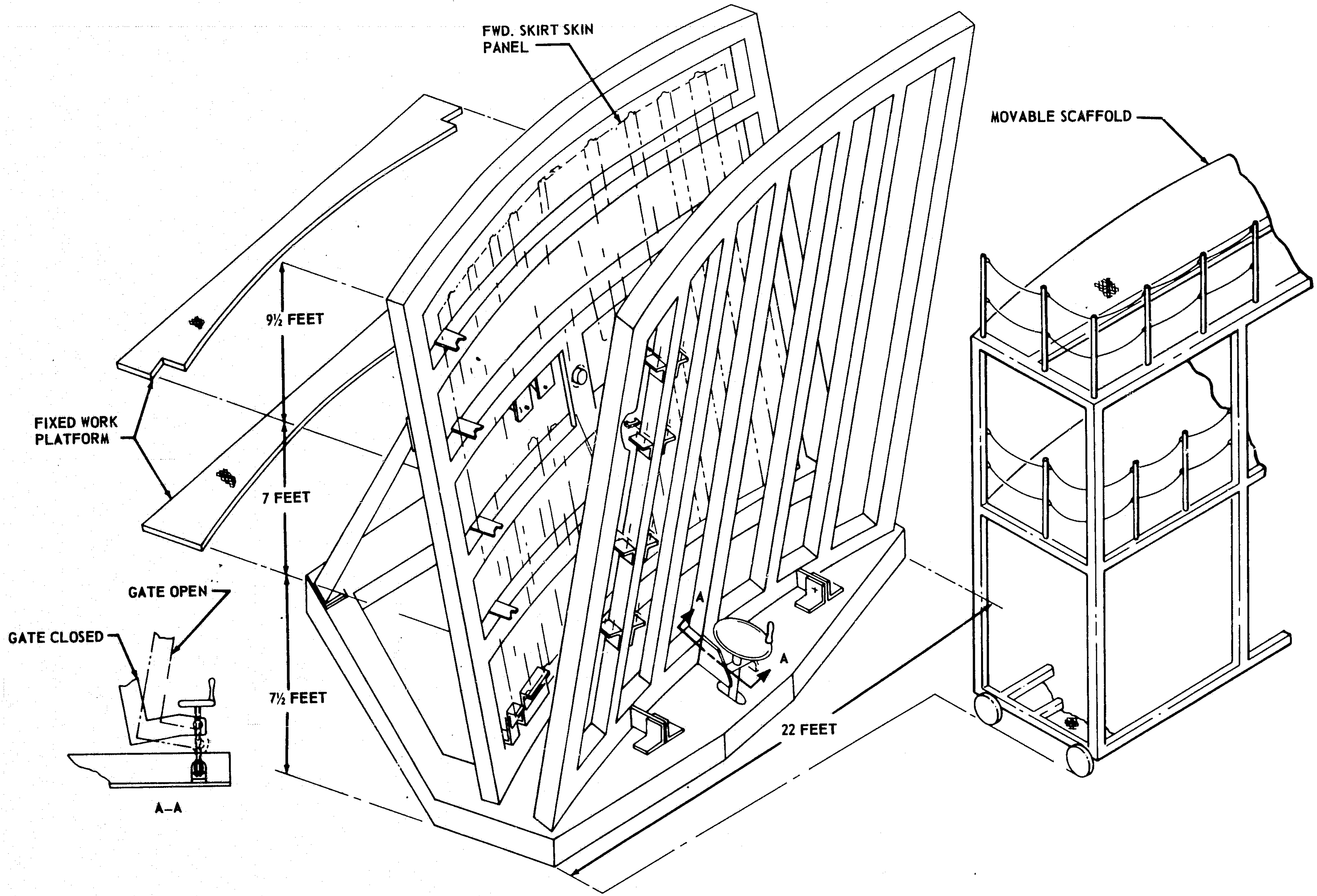


FIGURE 5.2.1.1-1 SKIN PANEL SUBASSEMBLY FIXTURE (AMLLV)

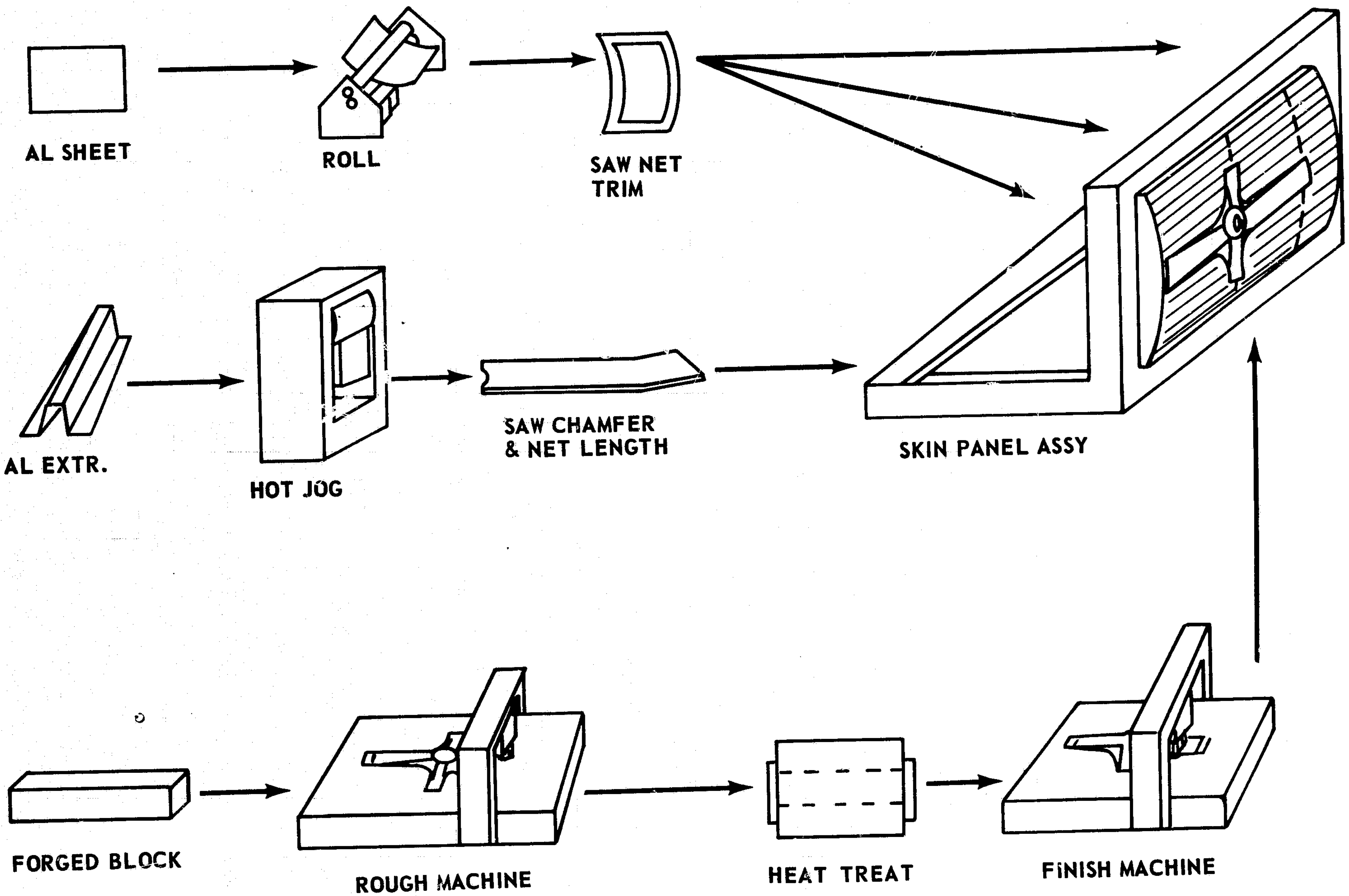


FIGURE 5.2.1.1-2 SKIN PANEL ASSEMBLY SEQUENCE

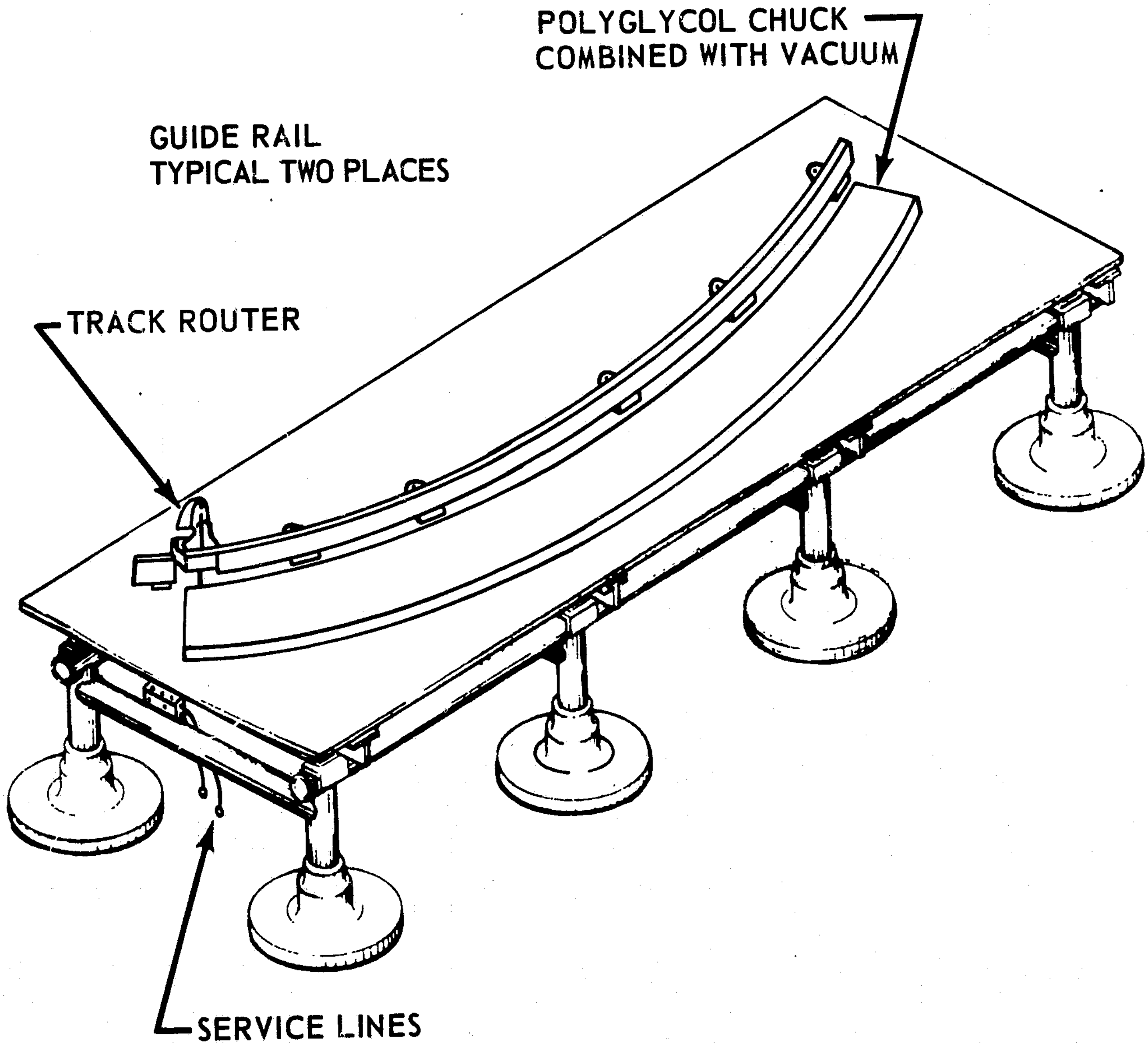


FIGURE 5.2.1.1-3 TRACK ROUTER TABLE WITH POLYGLYCOL CHUCK

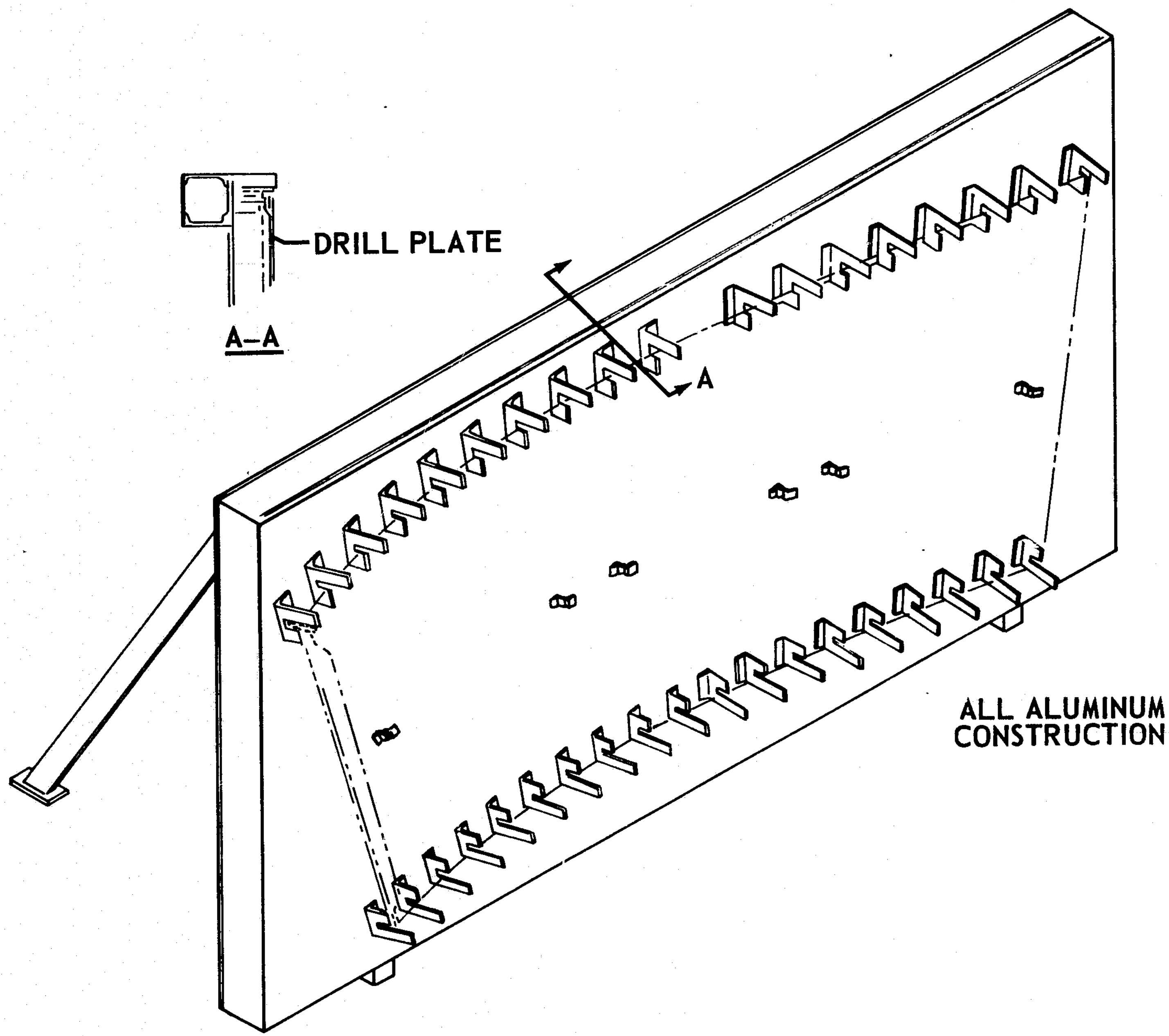


FIGURE 5.2.1.1-4 DEEP RING SEGMENT SUBASSEMBLY FIXTURE

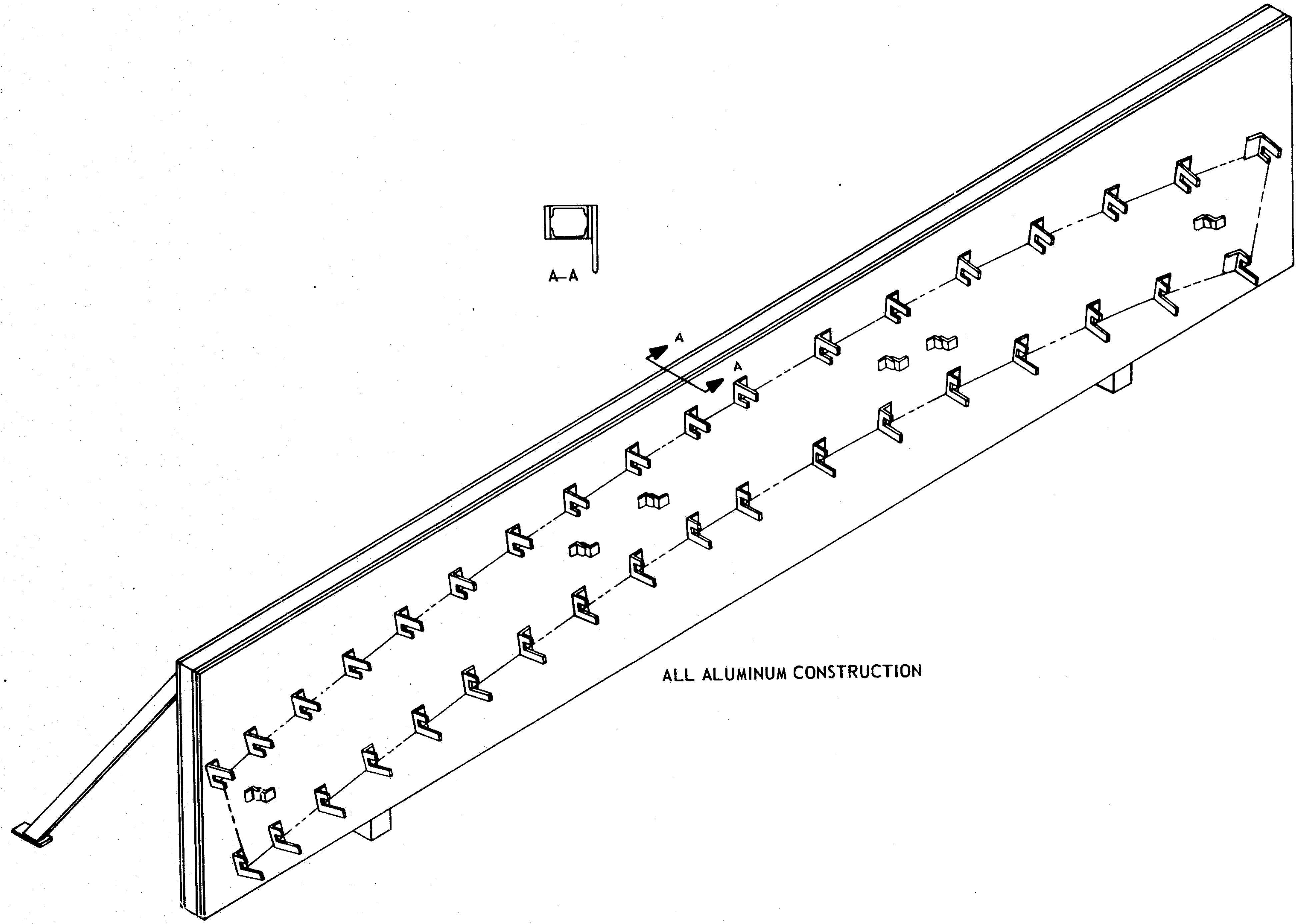


FIGURE 5.2.1.1-5 INTERMEDIATE RING SEGMENT SUBASSEMBLY FIXTURE

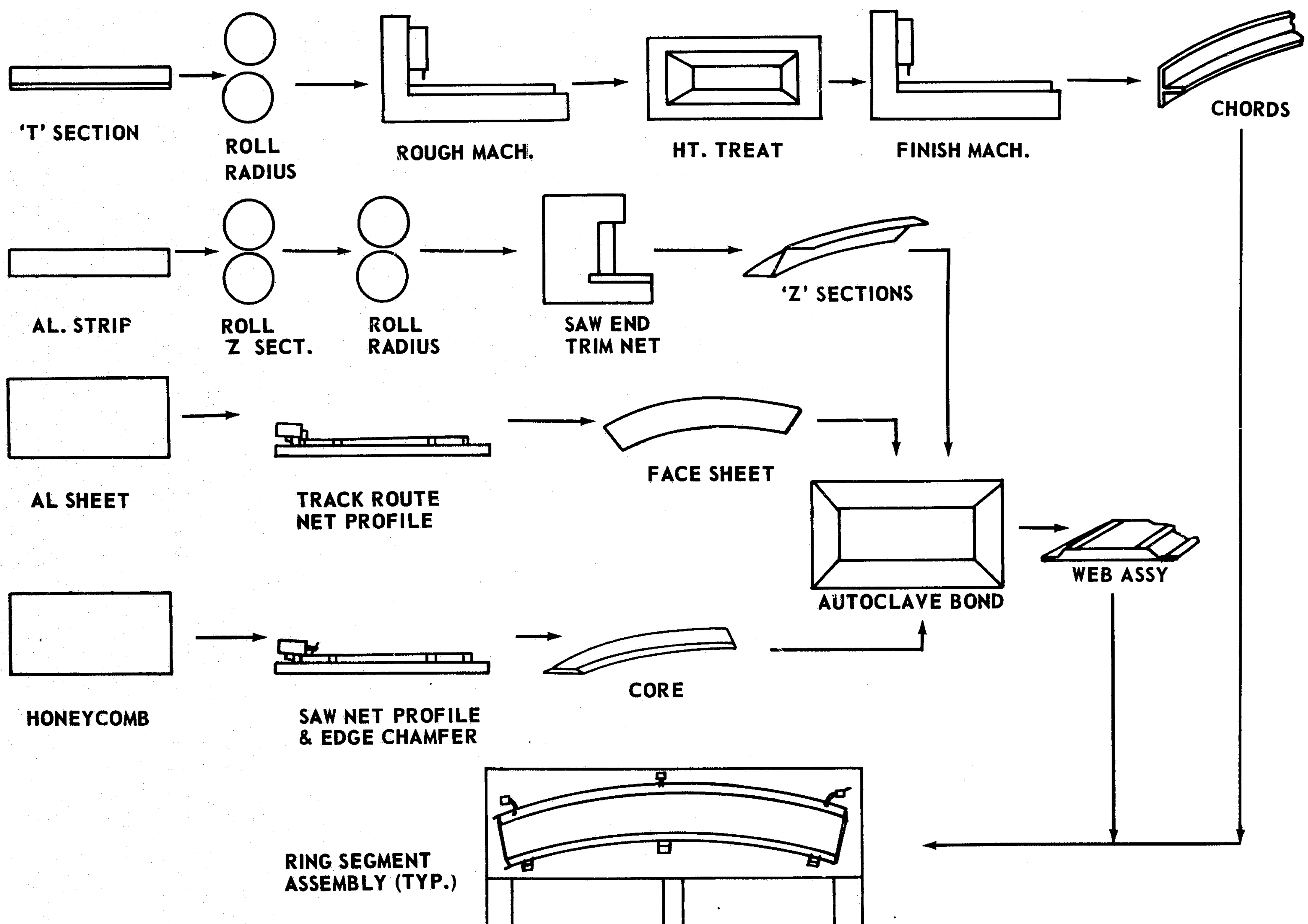


FIGURE 5.2.1.1-6 RING FRAME SEGMENT ASSEMBLY SEQUENCE

5.2.1.1 (Continued)

Interface Ring Frame Segments — The interface ring frame is composed of 12 segments. These segments are made from extruded aluminum, angle rolled to contour. They are placed on a boring mill, rough machined, removed and heat treated, reinstalled on the mill, and machine finished. The segments are then degreased, cleaned, conversion coated, and spray primed, Figure 5.2.1.1-7.

Backup Fittings — A backup fitting is installed at each ring-frame segment splice, and serves as a splice plate and additional stiffener at these locations. There is a backup fitting located next to each holddown or thrust post. Each of these has a recess to accommodate the shear pin retainer fitting.

This backup fitting is fabricated from an aluminum die forging, rough machined on a numerically controlled mill, heat treated, and machine finished. It is then degreased, cleaned, conversion coated, and primed, Figure 5.2.1.1-7.

Shear Pin Retainer Fitting — This fitting provides a recess for the holddown-arm shear-pins. It is fastened directly to the holddown post on the inside of the assembly. The shear pin retainer fitting is fabricated from an aluminum die forging, rough machined on a numerically controlled mill, heat treated, and machine finished. It is then degreased, cleaned, conversion coated, and primed, Figure 5.2.1.1-7.

5.2.1.2 Forward Skirt Final Assembly (Heavy Weight)

The forward skirt is assembled in an inverted vertical position. This permits firm tooling at the base of the assembly fixture, Figure 5.2.1.0-1, for controlling the interface attach hole pattern and station plane. If the assembly were built upright, the interface ring tooling would need to be removable to clear the deep ring frame when lifting the assembly from the fixture.

All ring frame segments, back-up and shear pin retainer fittings along with drill plates are loaded into the assembly fixture. Approximately 1000 (2400) holes are drilled to make ring splices. These parts are then removed, deburred, reinstalled in the assembly fixture, and permanently fastened.

Skin panel subassemblies, interface angle-ring segments, panel-splice doublers, and hat sections are positioned in the fixture, indexing to the completed ring frames and simulated Y-rings. Using drill plates, the attach holes common to the ring frames and skin assemblies (also interface angle-ring and skin assemblies) are drilled. The panels are removed and deburred, then relocated and permanently fastened. Fastener heads are touched up with primer. Lifting lugs are installed, and the forward skirt is removed from the fixture and inverted on the forward skirt inverting tool, Figure 5.2.1.2-1. Miscellaneous bracketry, access doors and umbilical frames are also installed. The final assembly sequence is depicted in Figure 5.2.1.1-7.

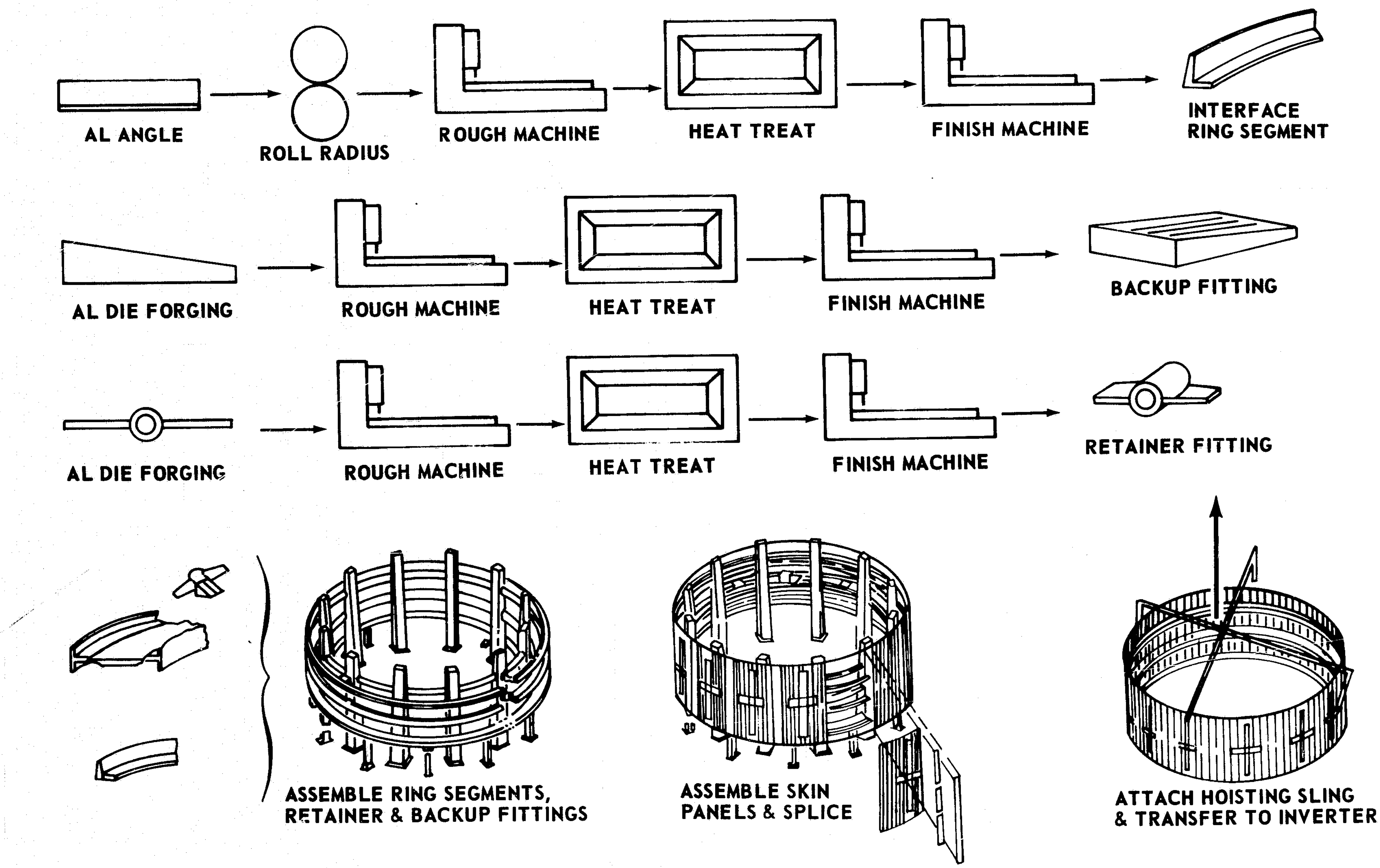


FIGURE 5.2.1.1-7 FORWARD SKIRT FINAL ASSEMBLY SEQUENCE

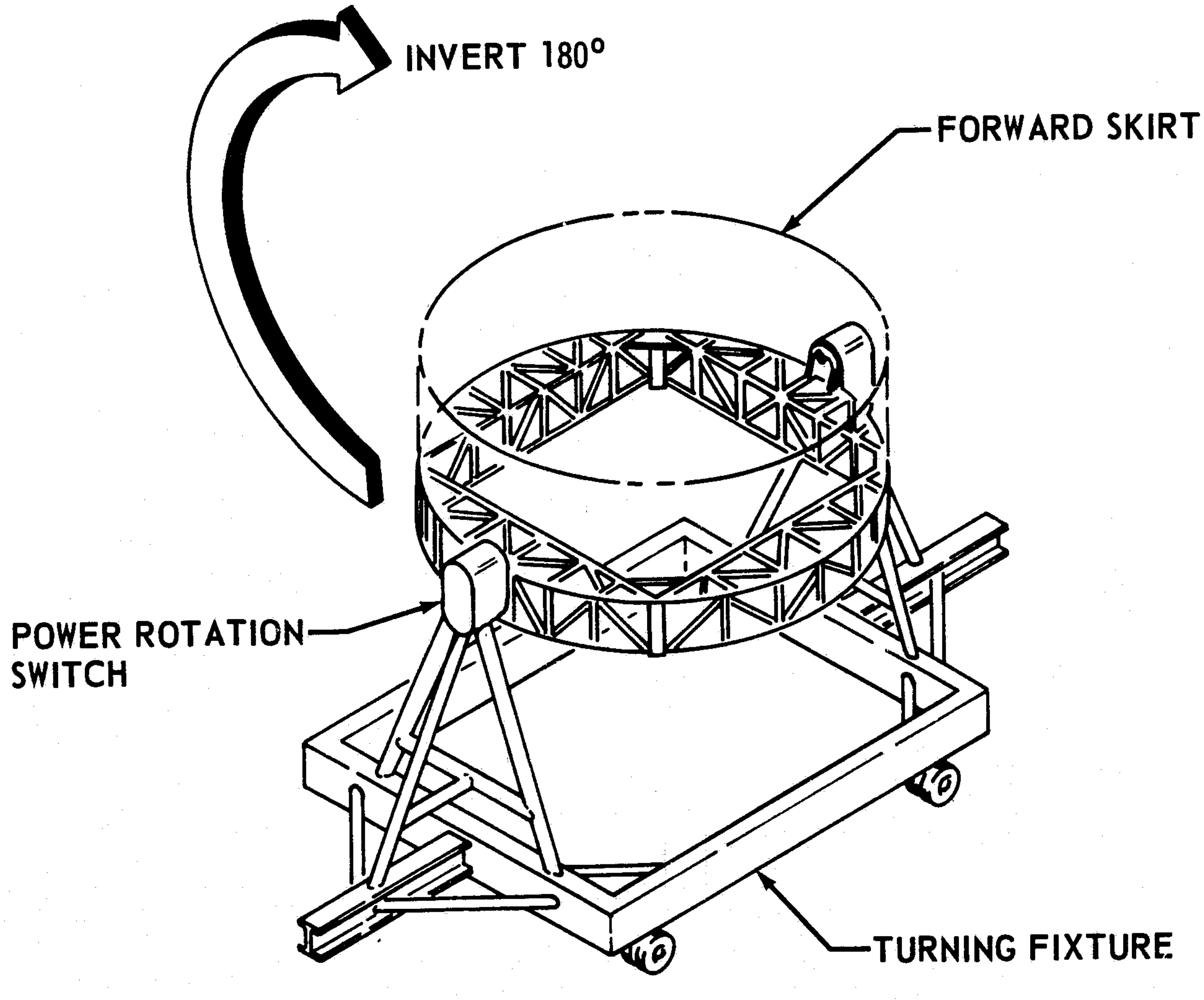


FIGURE 5.2.1.2-1 FORWARD SKIRT INVERTING FIXTURE

5.2.1.3 Forward Skirt (Lightweight)

The forward skirt described above in Paragraphs 5.2.1.1 through 5.2.1.2 is the heavyweight forward skirt used with the vehicle configurations employing strap-on SRM stages. For the single-stage-to-orbit vehicle and the main stage-plus-a-single-module-injection-stage vehicle, a lightweight forward skirt is used.

This skirt is fabricated in the same manner as the heavyweight forward skirt. The differences between the lightweight forward skirt and the heavyweight forward skirt are as follows:

a. The heavyweight forward skirt employs heavier skin and stiffener material gage thickness to withstand the increased axial loads;

b. The heavyweight forward skirt has four ring frames (one deep frame and three intermediate frames) while the lightweight forward skirt has three ring frames (one deep frame and two intermediate frames);

c. The heavyweight forward skirt has eight thrust posts for the MLLV [12 thrust posts for the AMLLV] to react the SRM strap-on stage loads. The lightweight forward skirt has holddown posts. The large thrust of the SRM requires that the thrust posts be considerably larger than the holddown posts.

The three differences shown above result in a significant increase in the forward skirt weight. These differences, however, do not impact the manufacturing plan for the forward skirt significantly. The description of the forward skirt, the manufacturing flow process, the tooling, capital equipment, materials of construction, fabrication methods and manufacturing schedules are nearly identical.

5.2.2 Propellant Tanks

The propellant tank is primarily a welded aluminum (2219-T87) structure employing welded T-stiffeners in the cylindrical sections. It is composed of upper and lower elliptical bulkheads welded from bulge formed gore segments and an insulated honeycomb, semi-elliptical common bulkhead. LOX is contained between this bulkhead and the upper bulkhead, while the space below the common bulkhead is the LH_2 tank. An anti-vortex cruciform baffle is located immediately above the inner face sheet of the common bulkhead and immediately above the LH_2 tank lower bulkhead. Cantilever-ring baffle assemblies extend inward from the common fitting ring of the common bulkhead and the welded T-stiffeners of the LH_2 tank. Twenty-four LOX tunnels feed through the LH_2 tank from a LOX duct manifold fitting in the center of the common bulkhead and penetrate the LH_2 tank lower bulkhead in the vicinity of each engine. LH_2 feed lines emanate from a fitting in the bottom center of the lower bulkhead and extend radially inside the LH_2 tank penetrating the bulkhead near each engine. The tunnels are tied together inside the LH_2 tank and braced with high-strength tension rods attached to collars which surround each tunnel. (NOTE: The twenty-four LOX and LH_2 lines are required with the multichamber/plug propulsion system. Only eight LOX and LH_2 lines are required with the toroidal/aerospike propulsion system.)

5.2.2.1 Bulkhead Description

The propellant tank consists of three oblate semi-elliptical bulkheads; the upper bulkhead which forms the top closure of the LOX tank, the lower bulkhead which closes the bottom of the LH_2 tank and the common bulkhead which separates the two tanks. Each upper and lower bulkhead is made from 16 [20] constant thickness (except for weld lands) 2219-T87 aluminum gore assemblies, a polar cap, and a machined ring. Use of 16 [20] gore assemblies permits the use of sheet sizes less than 12 feet wide per gore. The common bulkhead is a honeycomb structure with two aluminum face sheets, fabricated in a manner similar to the other bulkheads. These face sheets do, however, differ from the upper and lower bulkheads in that they are thinner, and their bases have short conical sections. One of the sections is welded to the common fitting ring and the other is adhesively bonded and mechanically fastened to the common bulkhead Y-ring.

Gores — The base gore and apex gore sections of the upper and lower bulkheads are machined in a flat pattern on an NC skin-mill. The fitting bosses are machined as integral parts of the sections. These flat gore sections as well as the common bulkhead face-sheet gore sections are bulge formed on bulge-form dies and heat treated on heat-treat fixtures to the T-87 condition. Gores may also be fabricated by first bulge forming and then chemical milling.

The formed apex and base gores are then vapor degreased and all rough fitting cutouts, such as the LOX tunnel and LH_2 duct penetrations of the lower bulkhead, are made if applicable.

A hoisting tool loads the gore onto a trim and weld fixture where it is located by tooling holes left in the excess material provided on all sides. The cutout is finish routed to net size using a router fixture located by a check gage. Fittings are then located in the gore cutouts and welded.

Following fitting welds, the gore is heat treated and the fittings are drilled and tapped for helicoil insertion. The gore is then cleaned and conversion coated.

Using a hoisting tool, the apex and base gores are located into gore trim-fixtures where their mating edges are outer trimmed net. They are then placed on a welding fixture and welded. All welds are X-rayed while on this fixture. The gore assemblies are then placed on a trim fixture equipped with router tracks, Figure 5.2.2.1-1, and trimmed net.

Polar Cap — The polar caps are fabricated on a standard boring mill from flat stock.

Rings — The upper and common bulkhead Y-rings, as well as the common fitting ring and junction fitting ring are fabricated from eight 2219-T87 aluminum billets rolled to contour and welded into a complete circle. The welds are X-rayed and repaired as required. Each ring is placed on a Niles type 57 [72] foot diameter boring mill and turned to shape.

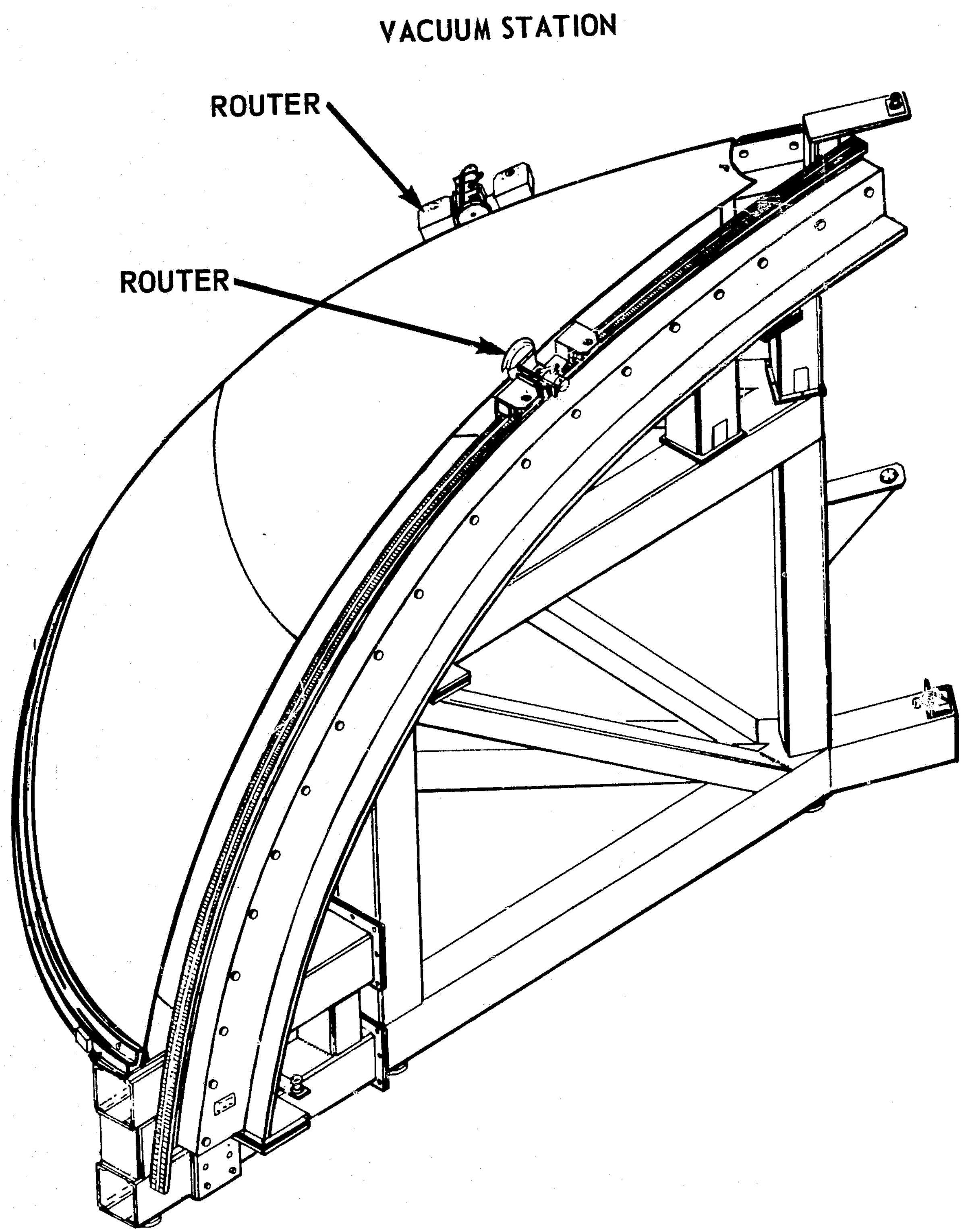


FIGURE 5.2.2.1-1 TRIM FIXTURE

5.2.2.1 (Continued)

Honeycomb Cores — The 5052 aluminum alloy honeycomb core is purchased in the thickness, size, and shape required for direct application to the bulkhead. Cutting and trimming of the core is thus minimized. The proposed flexible core will conform to the bulkhead contour with only hand pressure, so that no preforming will be necessary.

5.2.2.2 Bulkhead Assembly

The gore assemblies are placed one by one on a turntable and the meridian welds made using a suitable weld fixture, Figure 5.2.2.2-1. Each weld is X-rayed on assembly and repaired as needed.

Because of weld shrinkage, it will be necessary to trim the last gore assembly to fit. If trial shows that weld shrinkage is excessive, measurements will be made more frequently and compensating adjustments made on preceding gores prior to fitting the last gore.

When the welds are made and X-rayed, the head assembly is moved to the bulkhead skirt trim station which consists of a turntable, holding fixture, and router. The base of the head is then routed net.

Using a suitable handling ring, the Y-ring is now placed on the turntable of a combination Y-ring-to-bulkhead and polar-cap weld station, Figure 5.2.2.2-2. The head assembly is placed over the Y-ring and aligned. A polar-cap holding pedestal is located in the center which is capable of being raised and lowered.

The head assembly is welded to the Y-ring, using a boom weld fixture. The weld is then X-rayed and repaired as required. The polar-cap welding station is then raised against the bulkhead, and the polar cap is welded in place and X-rayed.

The bulkhead is dimensionally inspected by optical means prior to movement from this station thus eliminating another station with turntable. The foregoing assembly steps are depicted in Figure 5-2.2.2-3.

5.2.2.3 Common Bulkhead Assembly

The common bulkhead, upper face-sheet is fabricated convex upward in the same manner as described for the upper and lower bulkheads. The common fitting ring is also welded to the skirt of the upper face-sheet in a manner similar to that employed in welding the rings to the upper and lower bulkheads.

The common bulkhead is constructed of aluminum skins adhesive bonded to aluminum Flexcore. * The aft side of the bulkhead is exposed to LH_2 while the other is in contact with LOX.

Incompatibility of adhesive materials with LOX dictates a continuous welded, metallic surface on the LOX side. Thus the inner or LOX skin is completely welded. All weld

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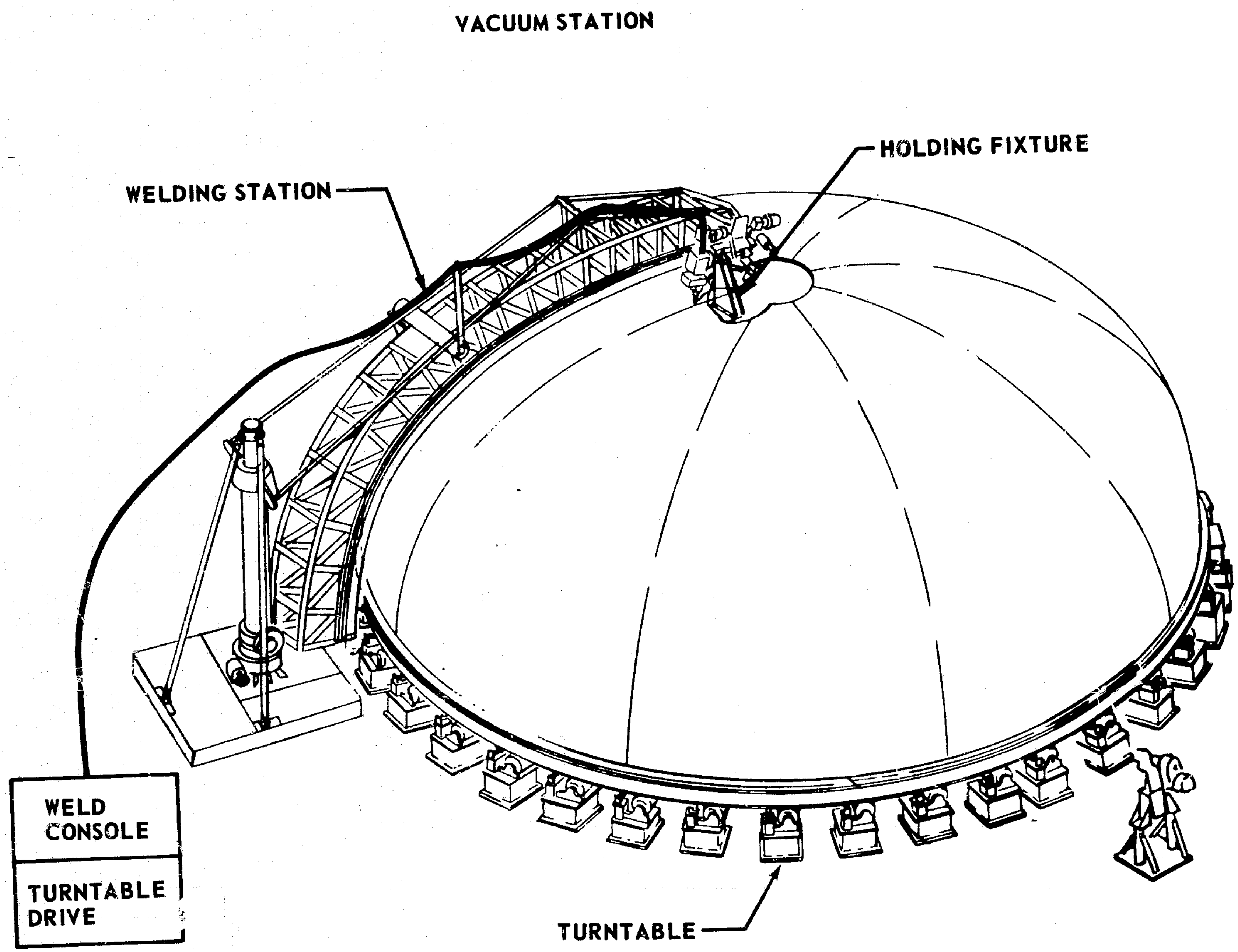


FIGURE 5.2.2.2-1 GORE TO GORE WELD STATION

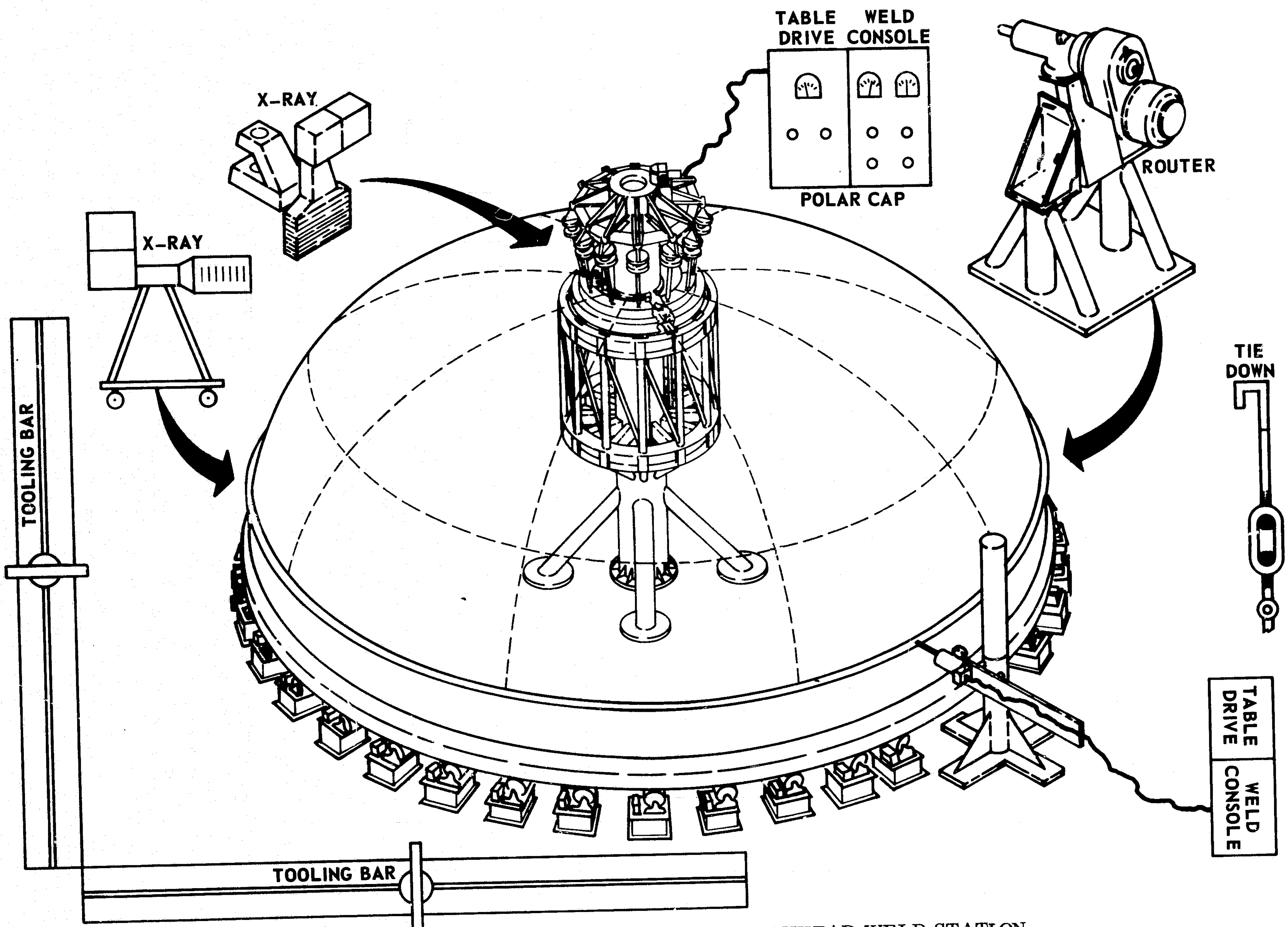


FIGURE 5.2.2.2-2 Y-RING AND POLAR CAP-TO-BULKHEAD WELD STATION

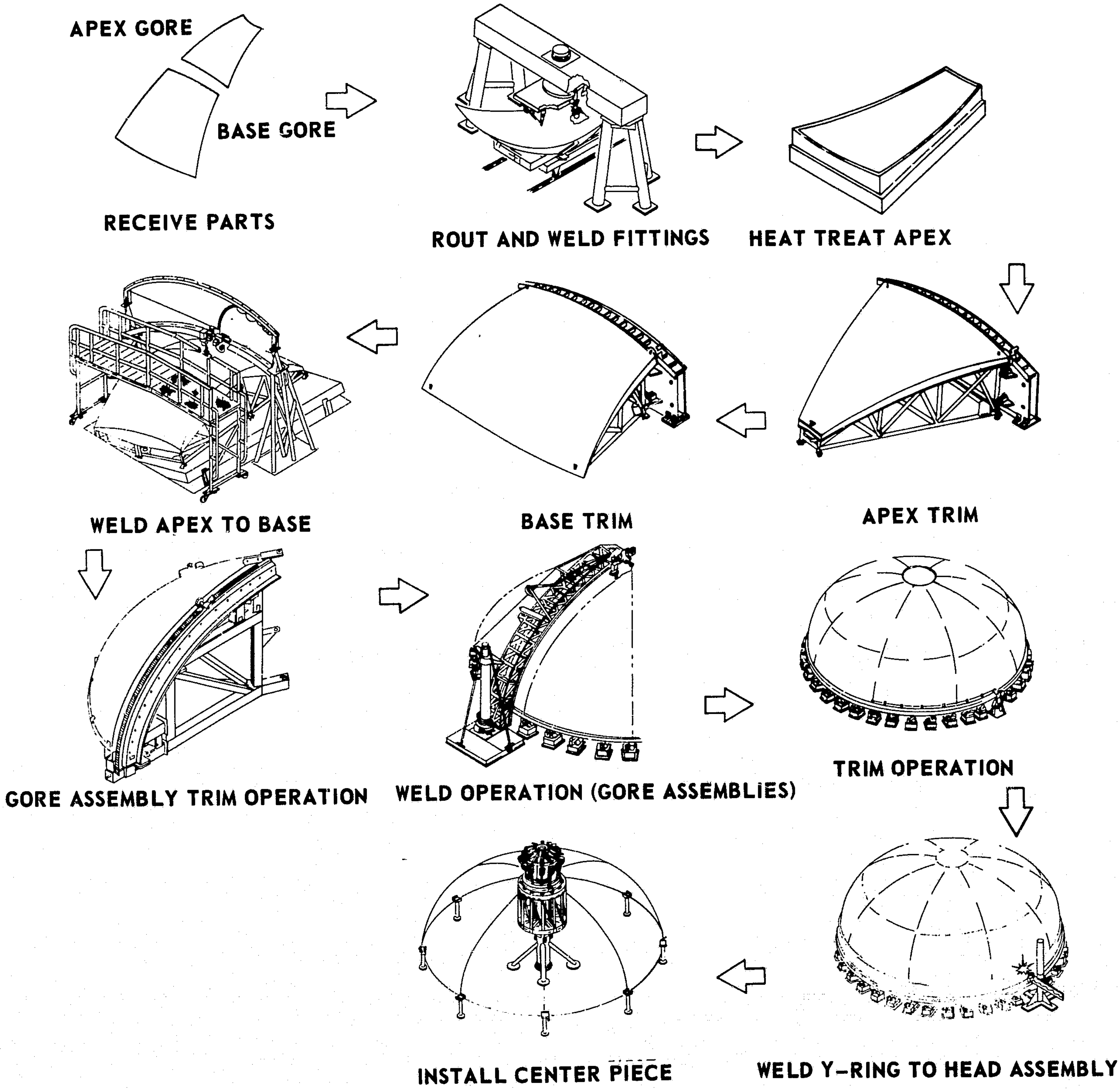


FIGURE 5.2.2.2-3 HEAD ASSEMBLY, BUILDUP SEQUENCE

5.2.2.3 (Continued)

beads are ground flush on the surface in contact with the honeycomb core. This is accomplished prior to prebond cleaning. The prebond cleaning operation is in accord with the standard industry accepted methods for cleaning aluminum for adhesive bonding — alkaline cleaning and deoxidizing with applicable rinse cycles. Areas which are excessively contaminated are hand solvent-wiped prior to prebond cleaning. Cleaning is performed only on the surface to be bonded.

The bulkhead skin-assembly is thoroughly dried and an adhesive primer is applied to prevent oxidization and provide time for subsequent operations.

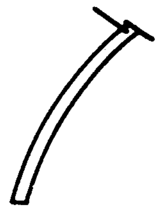
The primer dries at room temperature or slightly above, approximately 100 degrees F. Supplementary heat is provided by simple portable units traversing the primed surface. It is necessary that the primed surface be protected from airborne and other contaminants.

A film adhesive is applied to the primed skin, providing a uniform surface on which degreased Flexcore is laid. After the core panels (approximately four by eight feet) are positioned on the adhesive film, core-splice adhesive is placed between adjoining panels. This adhesive will flow, or foam, during the cure cycle, establishing a bond between panels. The lower bulkhead skin, LH_2 side, is fabricated from unwelded gore sections. These are cleaned, primed, and the film adhesive applied prior to positioning over the honeycomb core. The skins, which are butted together, are spliced by doublers bonded over the joints. These splice bonds are accomplished in the same manner as above. Details are held in position by heat tracking the adhesives, taping, and locating pins. The completed common bulkhead Y-ring with film adhesive applied is now moved into position onto the common bulkhead with the Y-ring handling fixture, aligned, and mechanically fastened, Figure 5.2.2.3-1.

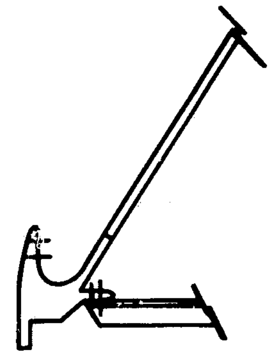
Bulkhead adhesive curing is accomplished using a temperature of approximately 250 degrees F and a pressure of 50-100 psi. The base for the lower concave surface is provided by a minimum support structure. The bulkhead is completely bagged on the LH_2 surface and sealed along the periphery of the LOX surface. This provides a complete seal to permit evacuation of the core and to prevent positive pressure from entering the core. When the autoclave facility is pressurized, a pressure differential of 50-100 psi is established across the sandwich panel, resulting in intimate contact between the face sheets and core during the cure cycle.

After cure, the Y-ring and common fitting ring are drilled for fastening. Holes are located by optically indexed drill plates. Next, plastic foam is pumped through these holes into the cavity between the Y-ring, common fitting ring, and honeycomb. After the foam has set,the Y-ring and common fitting ring are joined with Jo-bolts.

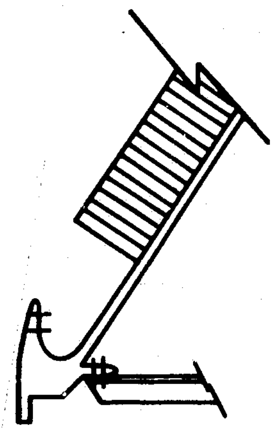
After joining the common fitting ring to the Y-ring, polyurethane foam is applied to the LH_2 side of the common bulkhead in the ensuing manner. The face sheet is etched with sodium dichromate and sulphuric acid, rinsed, and hot air dried. A coat of



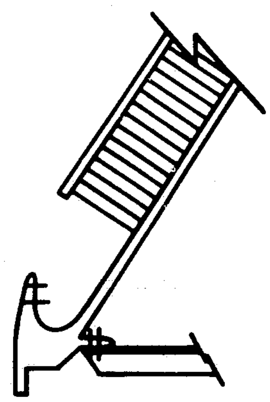
1. BUILDUP LOX TANK SIDE BULKHEAD



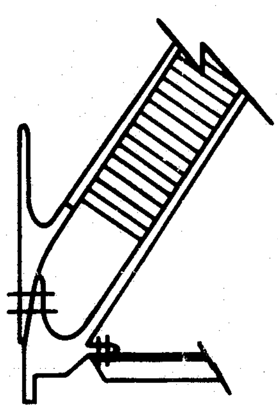
2. WELD COMMON FITTING TO BULKHEAD ASSEMBLY



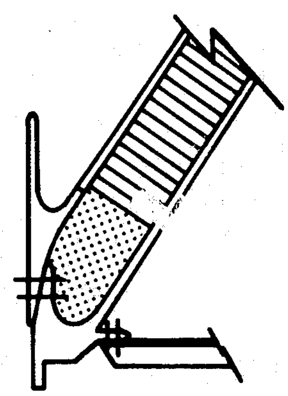
3. CLEAN BULKHEAD, APPLY FILM ADHESIVE & LAYUP ALUMINUM HONEYCOMB PANELS



4. LAYUP INDIVIDUAL GORE SECTIONS WITH DOUBLER JOINT AND CURE



5. MECHANICALLY FASTEN Y-RING TO COMMON FITTING AND LH_2 SIDE BULKHEAD



6. APPLY FOAM IN VOID AREA THROUGH FASTENER HOLES

FIGURE 5.2.2.3-1 COMMON BULKHEAD ASSEMBLY SEQUENCE

5.2.2.3 (Continued)

primer is then applied and allowed to dry. The foam is applied, cured, then sanded smooth. The final operation is the application of a coat of polyurethane resin.

At this point, the cruciform baffle is installed, then the completed bulkhead is moved on a transportation dolly to the vertical assembly area.

Every fabrication method for the common bulkhead which has been investigated portends problems which may materialize when actual hardware is built. A problem which may be encountered with the above method is the possible entrapment of hydrogen in the honeycomb core which has seeped through the bonded joints. Because this bulkhead is further insulated on the LH_2 side, and because a greater bond area must be permeated than on a corresponding welded structure, this method is deemed feasible. The common bulkhead assembly sequence appears in Figure 5.2.2.3-1.

5.2.2.4 Skin Panels

Present techniques for fabricating large cylindrical containers call for welding rolled skin panels into rings, then stacking and welding the rings together. Though satisfactory, this method involves a great deal of welding, much of which is horizontal. Horizontal welds have certain inherent disadvantages such as a tendency toward undercut and other flaws. To minimize welding and reduce the amount of horizontal welding, the baseline manufacturing approach will use 30 [40] skin panels approximately 38 (50) feet long for the LH_2 tank section. With the new skin mills now available, which have a capacity of 100 feet, this is well within the state-of-the-art. The LOX tank section, having only a very short cylindrical section, presents no problem.

Aluminum alloy skins, 2219-T87, approximately 50 feet long by 12 feet wide by 2 inches thick are transported by flatcar from the manufacturer to the fabrication site. Strongback handling fixtures are attached to the skins and they are transported on a dolly to the NC skin-milling area where longitudinal stiffener webs and weld lands are machined. The skins are then placed aboard the transportation dolly and sent to the T-section weld-station where extruded 2219-T87 aluminum T-sections, which have been stretched and faced along the weld surface, are located with suitable fixturing into position against the stiffener webs.

Butt welds are made using the out-of-vacuum electron beam welding technique, X-rayed, and repaired as needed. This is an advantageous approach in that no filler metal is required, only one weld pass is necessary, and the weld nugget is so small that there is negligible weld shrinkage. The inherent disadvantages of horizontal welds are not present with this weld method.

Welded skin panels are then transported to an aging oven, where a heat-treat fixture is used to form the radius. Allowance is made for springback. The panels are then removed from the oven and placed on a trim fixture where the skins are trimmed to proper length and width. The trimmed skin is then placed on a check fixture and dimensionally inspected. After inspection, the skins are cleaned, dye-penetrant

5.2.2.4 (Continued)

inspected, and conversion coated. The LOX tank skins are fabricated by a similar method. Vertical tank skin fabrication is shown in Figure 5.2.2.4-1.

5.2.2.5 Baffles

The propellant tank assembly includes cruciform baffle assemblies located in the bottoms of the LOX and LH_2 tanks and intermediate ring baffle assemblies in the LOX and LH_2 tanks.

Cruciform Baffles — The cruciform baffles are constructed from tubular struts welded into two crossed trusses with a common center post. These trusses attach to the bulkheads in four places, two places each truss. For example, on the common bulkhead the ends of the trusses fasten to the common fitting ring. A fine, wire-mesh web extends between the tubular members to retard movement of propellant within the tanks and to inhibit vortex formation. The cleaned and conversion-coated, cruciform members are located into an assembly fixture and welded together. The wire mesh is cut to size, cleaned and fastened to the truss structures. The entire assembly is then sent to the bulkhead assembly area, Figure 5.2.2.5-1. The cruciform baffles for both tanks are assembled in a similar manner.

Ring Baffle Segments — Ring-baffle web face-sheets and unformed Z-section flat-strips are cut to size. The face sheets are loaded into a track router fixture and trimmed net. The Z-section strips are rolled to the Z-shape and subsequently rolled to curvature. The Z-sections are then sawed to length and trimmed net. Face sheets and Z-sections are deburred, alkaline cleaned, rinsed, cleaned in a hot deoxidizing solution, rerinsed and dried. Surfaces to be bonded are sprayed with an adhesive primer. The adhesive film is applied to these surfaces just prior to bonding.

Honeycomb core panels are placed on a track router fixture that is equipped with a combination of polyglycol/vacuum chuck, profiled to net size and chamfered. The honeycomb is stabilized on the edges during machining with solidified polyglycol. The polyglycol is then rinsed from the honeycomb with hot water and the honeycomb cores are degreased and dried.

Z-sections, face sheets and honeycomb core are placed into the ring-segment bonding-fixture. A vacuum bag is placed over the assembly to apply even pressure to the face sheets. The entire assembly is moved into an autoclave for the curing cycle. When pressure is reached on the outer surface of the assembly, the vacuum side is vented to the atmosphere. After the adhesive has cured, the fixture is removed and the ring segment is allowed to cool. The web assembly is then degreased and conversion coated.

The inner and outer T-chords are made from extruded T-sections which have been rolled to contour and rough machined on a boring mill. The sections are heat treated, reinstalled on the mill, and machine finished. They are then degreased and conversion coated.

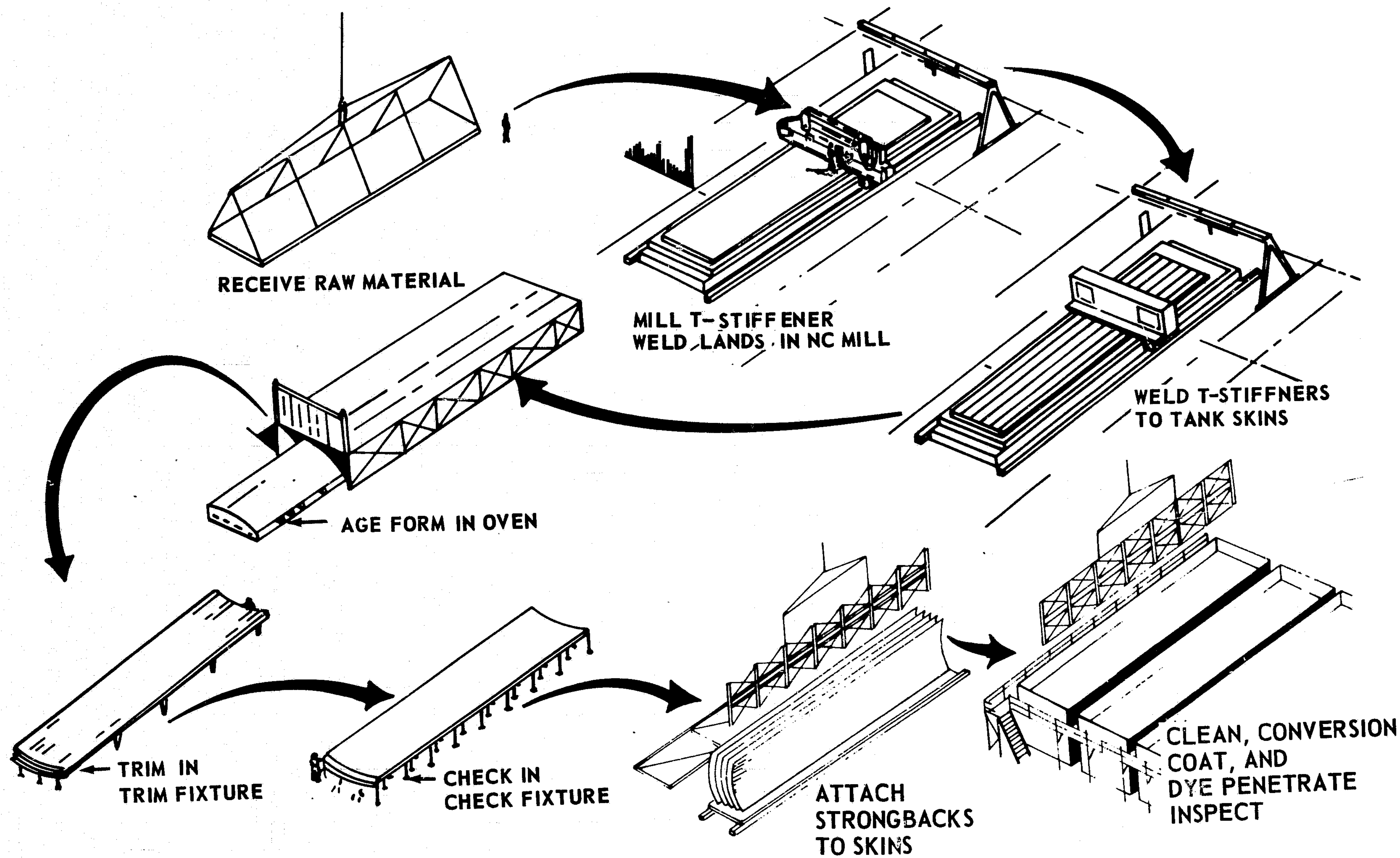


FIGURE 5.2.2.4-1 VERTICAL TANK SKIN FABRICATION

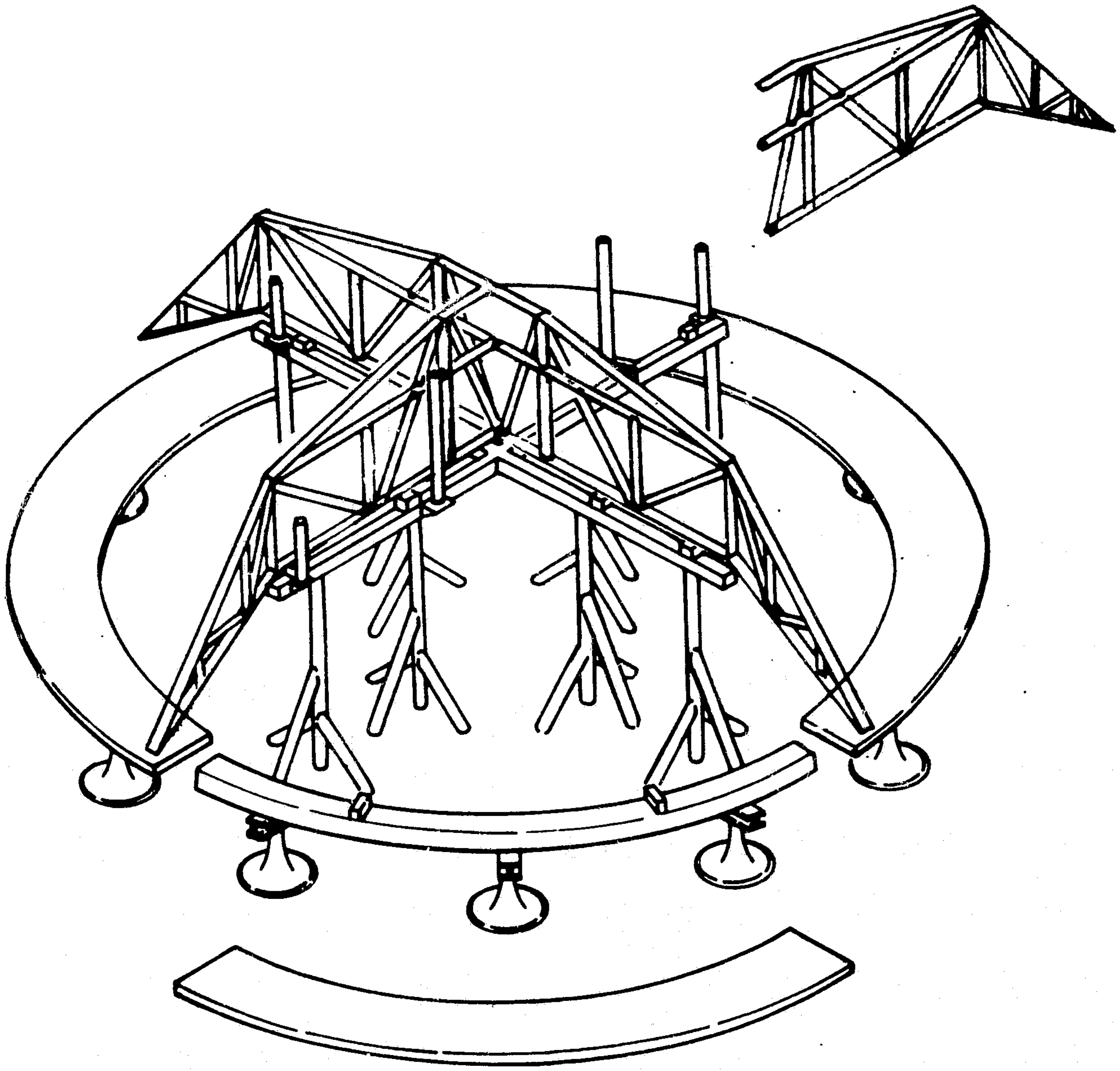


FIGURE 5.2.2.5-1 CRUCIFORM BAFFLE ASSEMBLY

5.2.2.5 (Continued)

The inner and outer chords, bonded web-assembly and drill plates are placed into a ring-segment subassembly fixture and clamped in place. Fastener holes are drilled then the parts are removed, deburred and replaced in the fixture. All fasteners which join the inner and outer chords to the web assembly are installed.

The ring baffle which attaches to a flange on the common fitting ring inside the LOX tank is not made of bonded honeycomb but is simply an inner T-cap riveted to a web stiffener with 2219-T87 aluminum angle riveted radially to the web. These segments are assembled in a conventional manner with tooling similar to that used for all other ring baffles.

Backup Fitting — The backup fitting is installed at each ring segment splice and serves as a splice plate and additional stiffener at these locations.

This fitting is fabricated from an aluminum die forging, rough machined on an NC mill, heat treated and machine finished. It is then degreased, cleaned and conversion coated.

5.2.2.6 LOX Tunnel

The LOX tunnel interior skin is produced from a single aluminum tube purchased to the required diameter. The tube exterior is cleaned using industry accepted cleaning methods. Portable or modular cleaning booths will be required due to the length of the tube. The tube is dried and adhesive primer is sprayed on the surface and dried. Film adhesive is applied to the primed surface and tacked in place. Aluminum Flexcore is then placed over the adhesive and core-splice adhesive is placed between the various core panels. Exterior skin panels, in manageable lengths, are cleaned and primed and the film adhesive is applied to the interior surface. The adhesive coated panel is then placed around the honeycomb to form the tunnel exterior skin. The skin panels are placed in position to form butt joints in areas different from those of the core splices. The entire assembly is then vacuum bagged so that autoclave positive pressure is exerted on all interior and exterior surfaces of the tunnel assembly. End fittings are preassembled on simple tooling prior to the assembly sequence described above. Splice doublers are bonded around the skin butt joints in a separate operation.

The length of the tunnel is such that the tunnel must be bonded in two equal length sections incorporating necessary joint members for joining to form a complete tunnel. This is necessary to permit use of the bulkhead autoclave facility. Several tunnel sections may be bonded during each cure cycle. The tunnels are spray-foamed by rotating them while moving the spray leads laterally at a prescribed constant rate.

5.2.3 Propellant Tanks Final Assembly

The propellant tank is made in two sections; an upper section containing the upper bulkhead, common bulkhead, LOX tank cylindrical section, cruciform baffles, and one 38 (50) foot LH_2 cylindrical section; and a lower section consisting of a 38 [50] foot cylindrical section, ring baffles, lower bulkhead, cruciform baffle, and LH_2 feed

5.2.3 (Continued)

lines. These LH_2 feed lines emanate from a fitting in the bottom center of the LH_2 bulkhead and extend radially inside the LH_2 tank penetrating the lower bulkhead near each engine. Twenty-four LOX tunnels feed through the LH_2 tank from a common fitting, LOX duct manifold, in the center of the common bulkhead and penetrate the LH_2 tank lower bulkhead in the vicinity of each engine. These tunnels are tied together inside the LH_2 tank and are braced with high-strength tension rods attached to collars which surround each tunnel. Each collar has a radial clearance of approximately 1/4-inch between collar and a rub ring attached to the duct. These loose collars, which are rigidly held in place by tension rods, act as radial dampers to inhibit vibrations. The lower cylindrical section, with ring baffles installed, is welded atop the lower bulkhead, with cruciform baffle installed, then the 24 LOX tunnels are installed. The common bulkhead, with cruciform baffle installed, is welded atop the upper cylindrical section. The LOX cylindrical ring is then welded to the common fitting ring, the ring baffle installed, and finally the upper bulkhead is welded to the LOX skin. The upper section is then placed atop the lower section and the closeout, circumferential weld is made at the junction of the two 38 (50) foot cylindrical sections. These operations are shown in Figure 5.2.3.0-1.

5.2.3.1 Upper Tank Section

Cylindrical Section Assembly — Tank skins with strongbacks attached are delivered on a transportation dolly to the vertical assembly building, Figure 5.2.3.1-1. Here the skins are transferred from the strongbacks to vacuum-chuck fixtures which accurately maintain skin contour and minimize longitudinal camber, Figure 5.2.3.1-2. Two skins are raised into position on the assembly fixture turntable and the bottom edges of the skins are lowered into skin shoes. The edges of the skins are aligned optically, sighting against offset targets located at the top and bottom of each skin. The first skin is held in place with a vacuum chuck and truss bottom attached on one end at the center of the turntable. The other end of the boom attaches to a clamp at the center, top, edge of the skin. A turnbuckle near the base of the boom will allow adjustment of boom length to establish normalcy of the skin in the radial plane. Adjustment in the shoes will permit vertical alignment in the plane tangent to the arc of the skin. The second skin is located adjacent to the first skin and optically aligned. Adjustment is made in the skin shoe as before and radial verticality is established by adjusting the length of an arm clamped to the top of the skin. The other end of the arm is attached to a fixed tower located outside the skin cylinder. This same tower has a post with rack and pinion arrangement to permit vertical travel of a router/welder boom having a personnel seat. The two skins which have not been aligned are simultaneously routed vertically. The second skin is moved laterally to butt against the first and then re-aligned. An out-of-vacuum electron beam welder replaces the router, and the weld is made with one pass. The turntable is re-indexed and a third skin with vacuum chuck is installed. It is aligned and welded as before. Optical angular measurements are made with the addition of each skin to continually adjust for compounded error. The fourth skin utilizes the vacuum chuck which was removed from the second skin and so on around the cylinder, so that only three vacuum chucks are necessary. The sixth skin is held with another boom in the same manner as the first. There are four booms

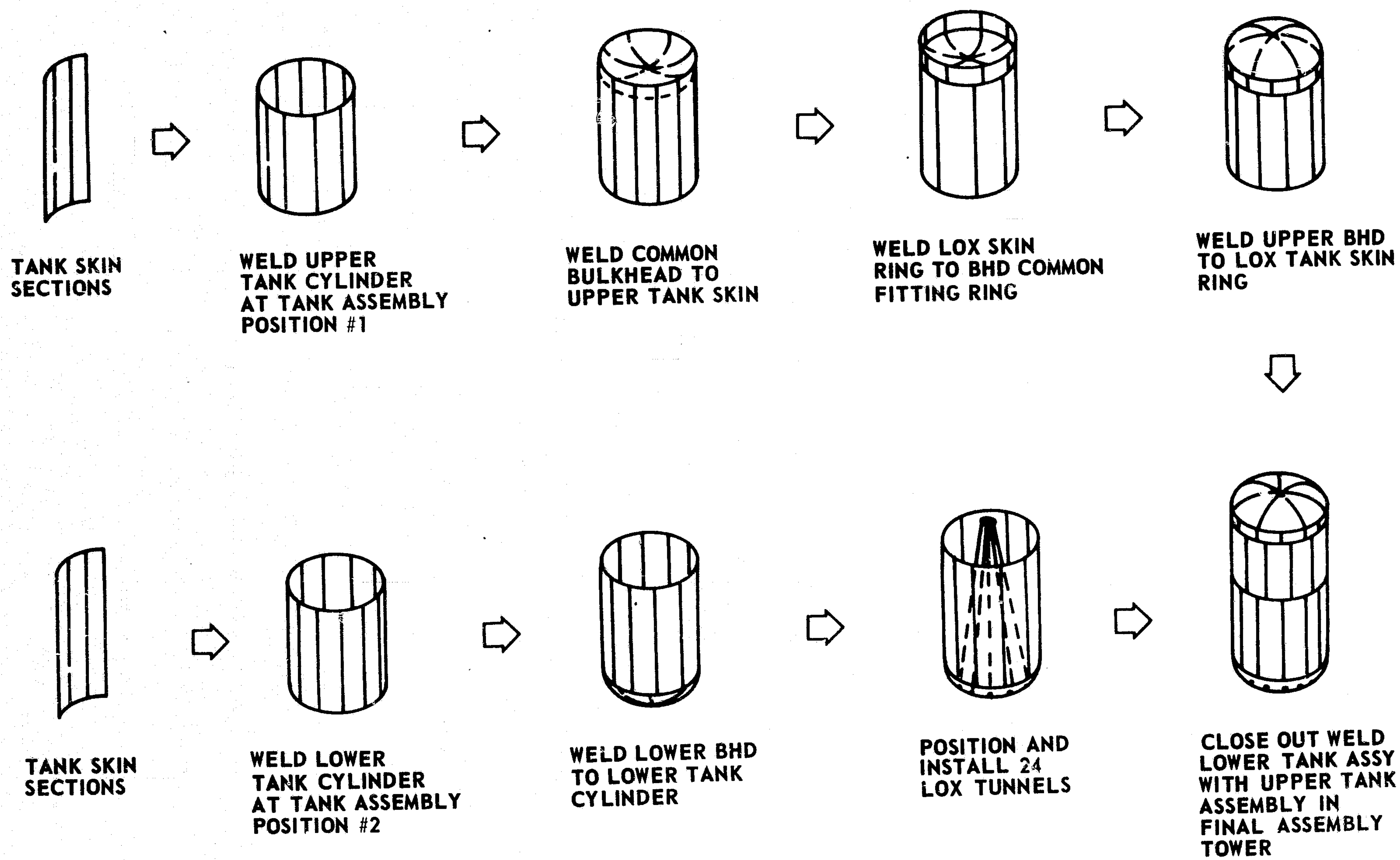


FIGURE 5.2.3.0-1 TANK ASSEMBLY SEQUENCE

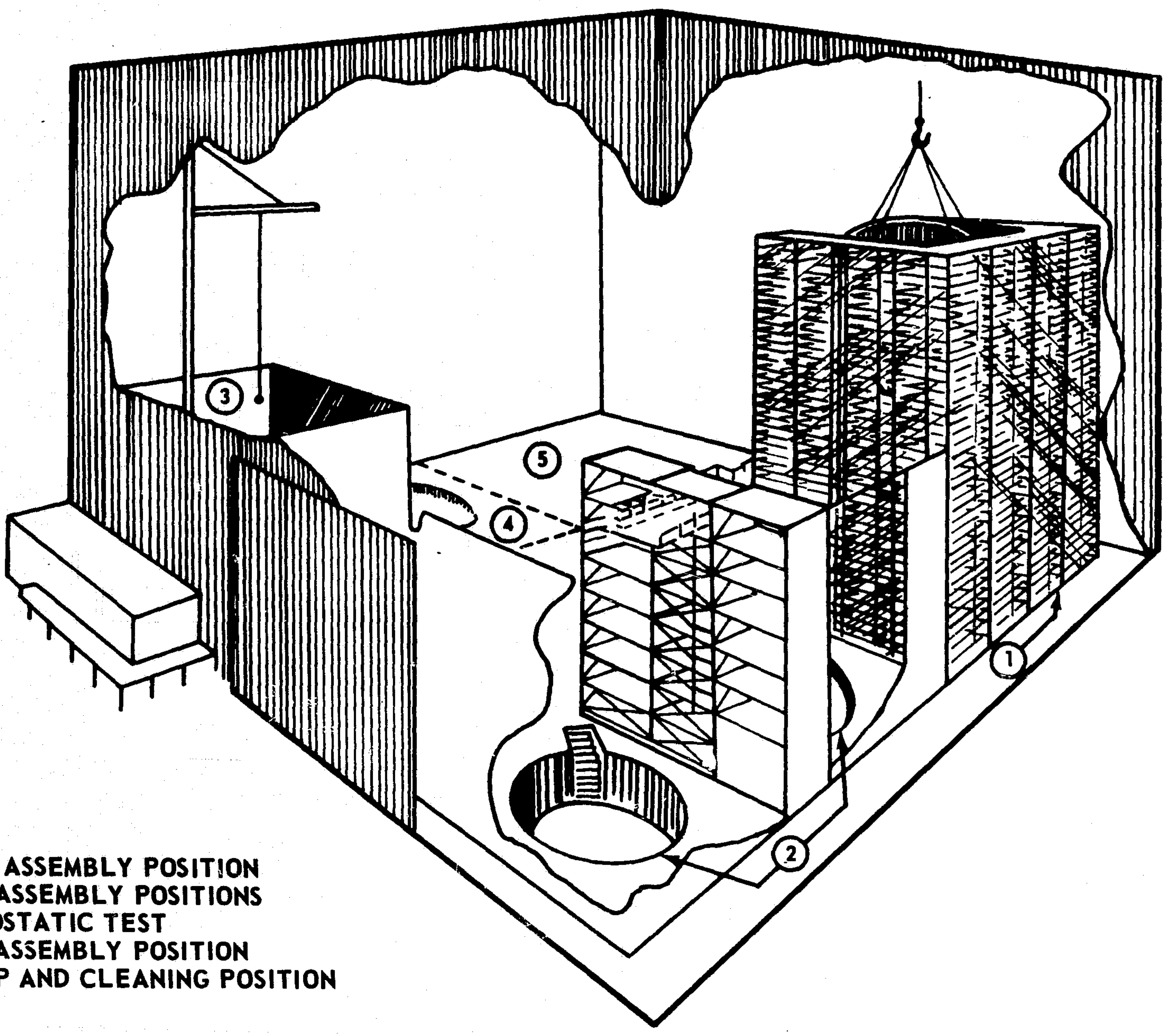


FIGURE 5.2.3.1-1 VERTICAL ASSEMBLY BUILDING

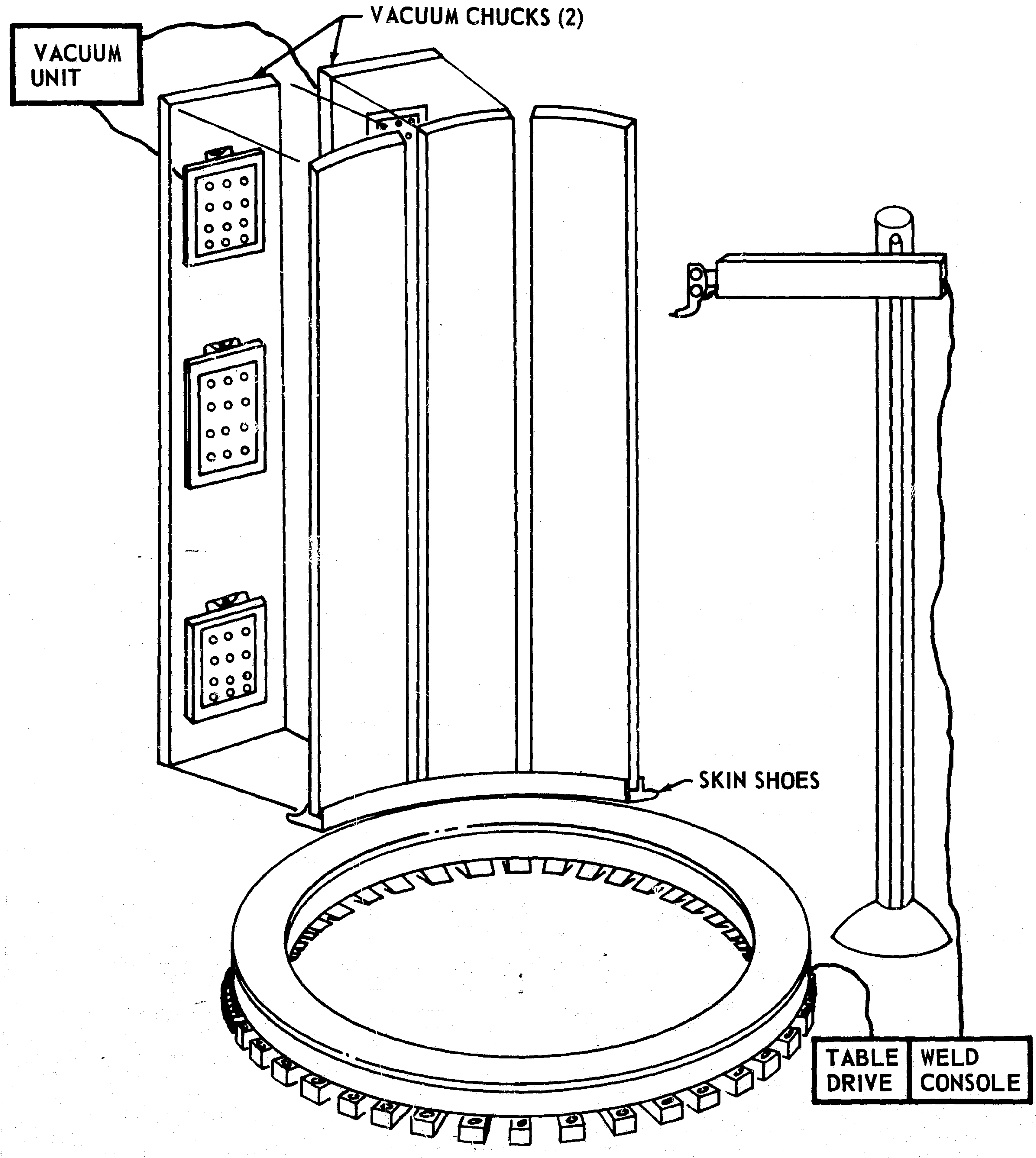


FIGURE 5.2.3.1-2 SKIN CYLINDER ASSEMBLY

5.2.3.1 (Continued)

located 90 degrees apart. Following the last vertical weld, all welds are X-rayed and repaired as required. When the cylinder is closed the router is raised to the top of the cylinder, the cylinder is rotated, and the top edge is trimmed. The base of the cylinder is also routed in a manner similar to the bulkhead skirt trimming operation. When the skin cylinder is completed, the booms are removed and 24 tooling bars, with locating holes at each ring-baffle station, are installed vertically at equal distances apart behind the welded T-stiffeners and clamped into position. Access is provided by a personnel platform which is lowered by three synchronous winches into the cylinder. The platform is equipped with shock bumpers to prevent damage to the vehicle. Detachable gussets are located by tooling bar holes and clamped into position. The ring-baffle segments are placed in position on the gussets, drilled in place, removed, deburred, replaced, and mechanically fastened. When all segments are installed, they are then spliced together with backup fittings.

The gussets are removed, and the personnel platform raised to the next set of tooling holes on the tooling bar. The above steps are then repeated. This is continued until all rings are installed in the cylindrical section. The completed cylinder is moved to a pickup position using a special handling ring.

LOX Tank Assembly, Common Bulkhead Buildup — The common bulkhead is inverted on the bulkhead inverting tool, and the cruciform baffle lowered into position. It is then mechanically attached to the common fitting ring, upper face-sheet, and LOX manifold fitting at the points provided. The assembly is then moved to a pickup position where it is then placed atop the upper LH_2 cylindrical section and welded in place.

LOX Tank Assembly, Cylinder Assembly — The LOX tank cylinder is constructed in a manner similar to the large LH_2 cylindrical section except that elaborate holding devices such as the vacuum chucks and center booms will not be necessary.

LOX Tank Assembly, Cylinder to Common Bulkhead Assembly — The LOX tank cylinder is then placed on the common bulkhead, aligned, and welded to the common fitting ring. At this point, the ring-baffle assembly is located within the LOX cylindrical ring and mechanically fastened to a flange on the common fitting ring.

LOX Tank Assembly, Closeout Weld — The upper bulkhead, which has been completed prior to delivery to the VAB, is placed atop the LOX cylinder and the mating edges are held together with clamps, Figure 5.2.3.1-3. The joint is tack welded, clamps removed, circumferential weld made, X-rayed, and repaired as needed.

5.2.3.2 Lower Tank Section

Lower LH_2 Cylindrical Section — The lower cylindrical section is identical to the upper cylindrical section. It is assembled as previously described and moved to a pickup position.

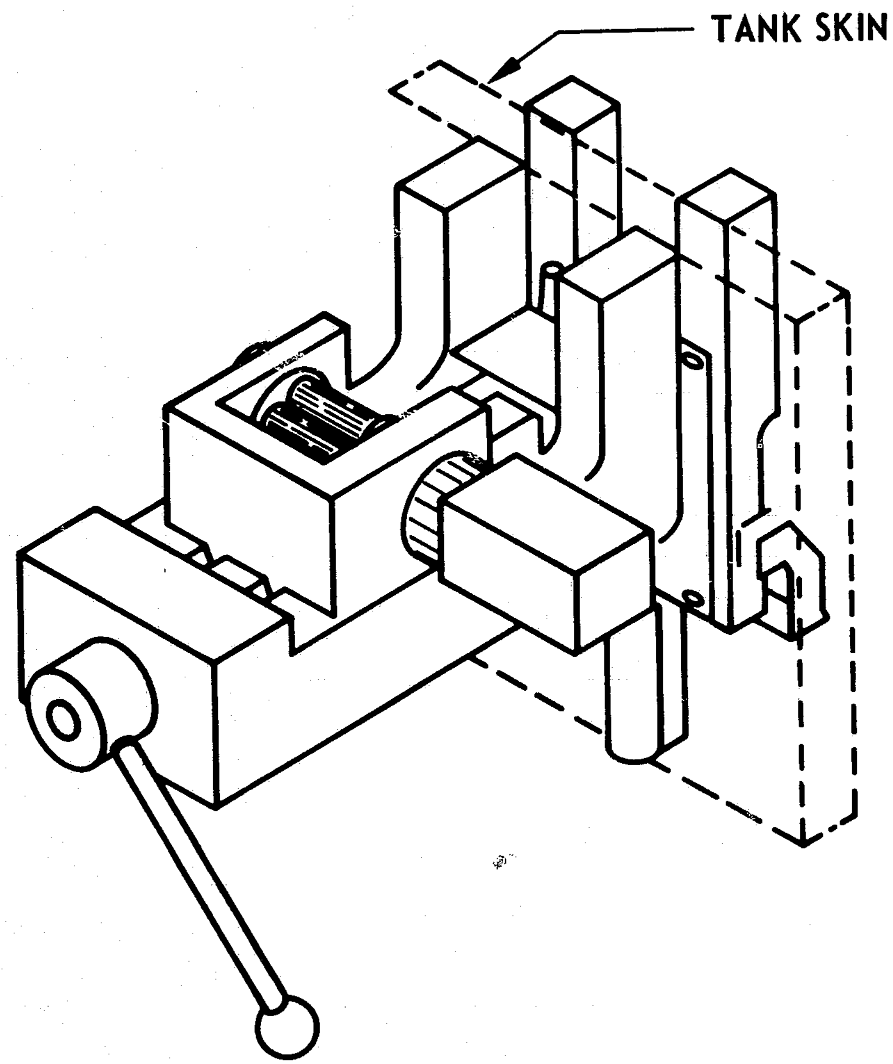


FIGURE 5.2.3.1-3 WELD FIXTURE ASSEMBLY ALIGNMENT CLAMP

5.2.3.2 (Continued)

Lower Bulkhead Buildup — The lower bulkhead with LOX and LH_2 ducts installed is inverted and lowered onto the turntable with support fixtures, Figure 5.2.3.2-1. Installation of the LH_2 manifold and cruciform baffle is then accomplished.

Lower Bulkhead to LH_2 Cylindrical Section Assembly — Upon completion of the lower bulkhead buildup, the completed lower cylindrical section is moved from the pickup position and lowered onto the lower bulkhead, junction fitting ring and welded as before. Each honeycomb LOX tunnel is raised from the horizontal to an inclined position. It is supported at the proper angle by a handling fixture which attaches to each tunnel collar. It is lowered into the lower tank section and attached at the base fitting. Tension rods are installed between the side wall and each collar. Each handling fixture attach-hook is then removed. All tunnels are installed in this manner and the top bellows are fastened to the manifold fitting which will mate with the adapter fitting of the common bulkhead. Using a cherry picker type crane with bumper interlocks to prevent damage to the vehicle, all succeeding tension rods are installed and turnbuckles torqued to a predetermined value.

5.2.3.3 Upper to Lower Section Assembly

The upper section is placed atop the lower section, optically aligned, clamped into position, circumferentially welded, and X-rayed. During the mating operation, the LOX manifold fitting is guided and nested into the common bulkhead adapter fitting and attached.

The completed propellant tank is now moved with a hoisting fixture to the hydrostatic test position where operational pressure simulation is applied by using differential water levels inside and outside the tank.

5.2.4 Aft Skirt

The aft skirt section is a mechanically fastened assembly consisting of skin-panel subassemblies, thrust posts, intermediate-ring segments, thrust-ring segments, inner splice-plates, centerbody plus post-attach fittings, and oxidizer/fuel pressurization manifolds with their respective attach fittings.

Each of the skin panel subassemblies consists of a single preformed 7075-T6 aluminum sheet. Twenty hat sections extending the full length of the panel, are mechanically fastened to each skin panel. Each hat section is reinforced with outer splice-plates at the upper end of the skin panel to provide additional strength at the lower bulkhead Y-ring attach points. An inner splice-plate is also used in final assembly to provide an interface surface between the rear of the lower bulkhead Y-ring and the skin panel inner surface.

The intermediate ring is assembled in the final assembly fixture using the preformed segments. Each segment is mechanically fastened to the inner side of the thrust posts.

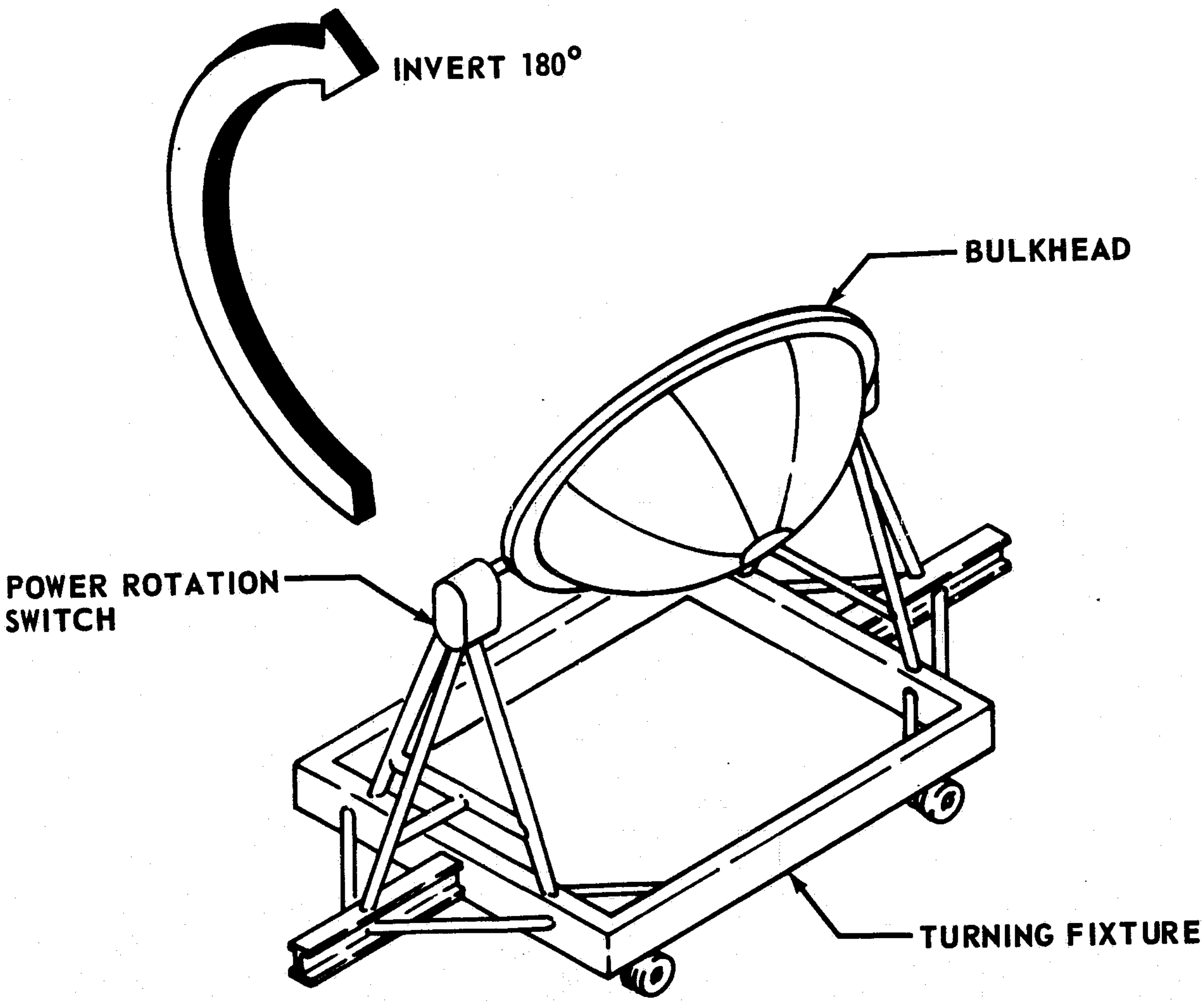


FIGURE 5.2.3.2-1 BULKHEAD INVERTING FIXTURE

5.2.4 (Continued)

The lower thrust-ring assembly forms the base of the aft skirt structure when its eight ring segments are positioned and joined in the major assembly fixture.

Both the intermediate and thrust-ring segments are constructed of inner and outer rolled aluminum T-chords. The bonded honeycomb web segments are mechanically fastened to the inner and outer caps.

5.2.4.1 Aft Skirt Subassemblies

The aft skirt is comprised of four subassemblies which are discussed in the following paragraphs.

Skin Panels — Aft skirt skin panels are rough cut, then rolled to the proper curvature from raw sheet stock. Hat sections are cut to length from extrusion stock, and hot formed with the proper end upset for correct alignment with the lower bulkhead Y-ring. Skin panels, hat sections, and outer splice-plates are loaded into the skin panel subassembly fixture, Figure 5.2.4.1-1. Fastener holes are drilled with the aid of drill plates and automatic air-feed drillmotors. All parts are removed, deburred, cleaned, and reloaded into the fixture. Hat sections are then clamped to the skins and permanently fastened. Outer splice-plates are located, pilot drilled, and fastened in place using cleko fasteners. Final attachment of this item will be accomplished in vertical assembly with the lower bulkhead Y-ring. Personnel platforms, as shown in Figure 5.2.4.1-2, will be used to provide access to the upper extremeties of the subassembly fixture. These platforms are portable and are moved away when the completed skin panel is removed and placed on a transport/storage dolly with a hoisting sling similar to the one shown in Figure 5.2.4.1-3.

Thrust and Intermediate Ring Segments — Due to their similarity in design, fabrication of the thrust and intermediate ring segments is essentially the same. The inner and outer T-chords, Z-strips, and upper and lower face-sheets are cut to size and rolled to the proper curvature as required. A track router similar to the one shown on Figure 5.2.4.1-4 will be used to trim the face sheets. All access holes for LOX and fuel lines will be made in this fixture. All face sheets, T-chords, and Z-sections are deburred, alkaline cleaned, rinsed, recleaned in a hot deoxidizing solution, rerinsed, and then dried. Rough formed honeycomb cores are also placed in a track router. A combination vacuum/polyglycol chuck is used to hold the structure firm while excess material is removed. When all cutting and routing operations are completed, the hardened polyglycol is rinsed away with hot water. Completed honeycomb sections are once again degreased and dried. Adhesive primer is then applied to those surfaces which are to receive a bonding agent.

Final assembly of the thrust ring segments is accomplished in a fixture similar to that shown on Figure 5.2.4.1-5.

A hoisting sling, Figure 5.2.4.1-6, is used to load Z-sections into the ring segment bonding fixture. Face sheets are coated with an adhesive bonding agent, and loaded into the fixture along with LOX and fuel fitting rings (similar to procedure used for the thrust

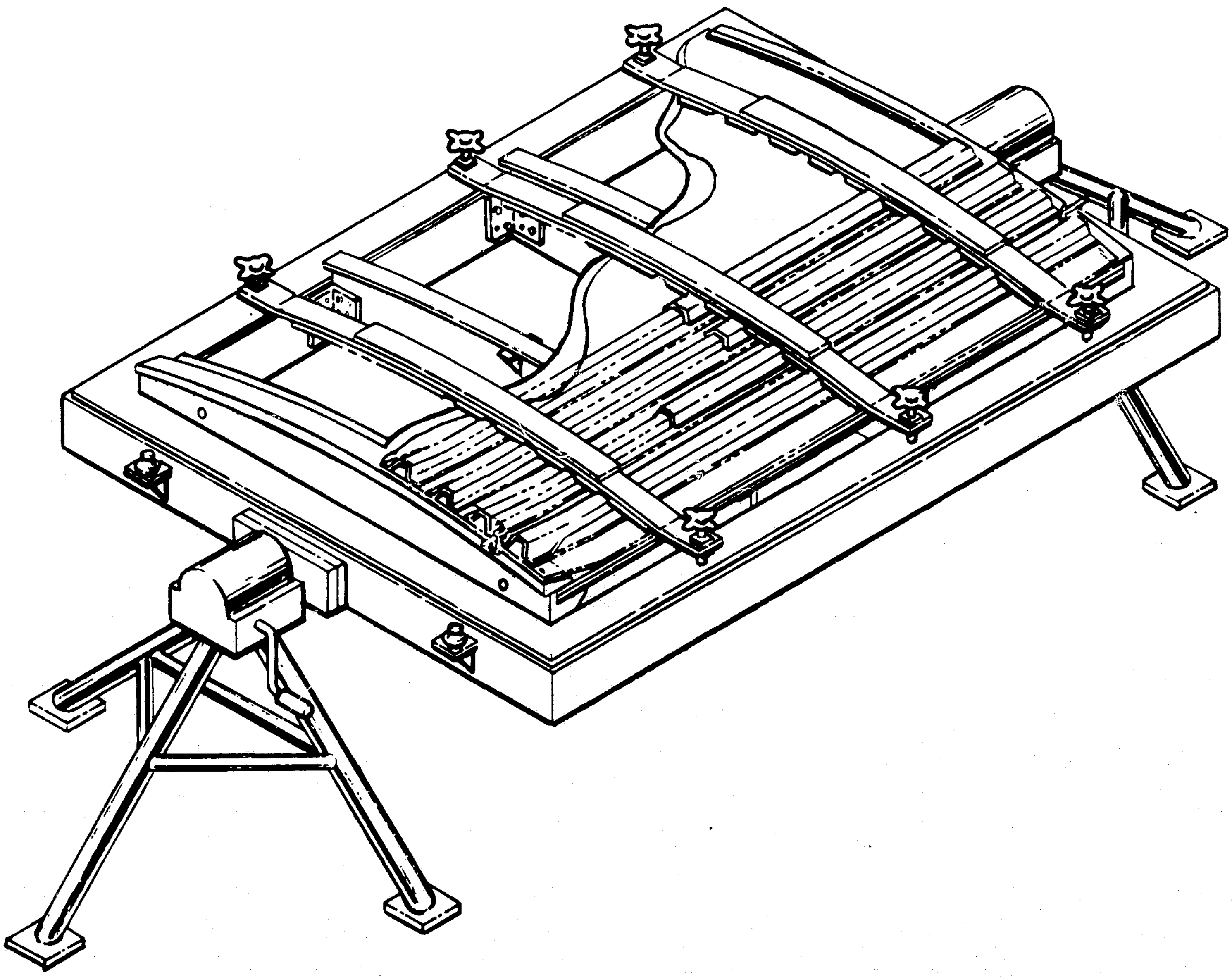


FIGURE 5.2.4.1-1 AFT SKIRT SKIN SEGMENT ASSEMBLY FIXTURE

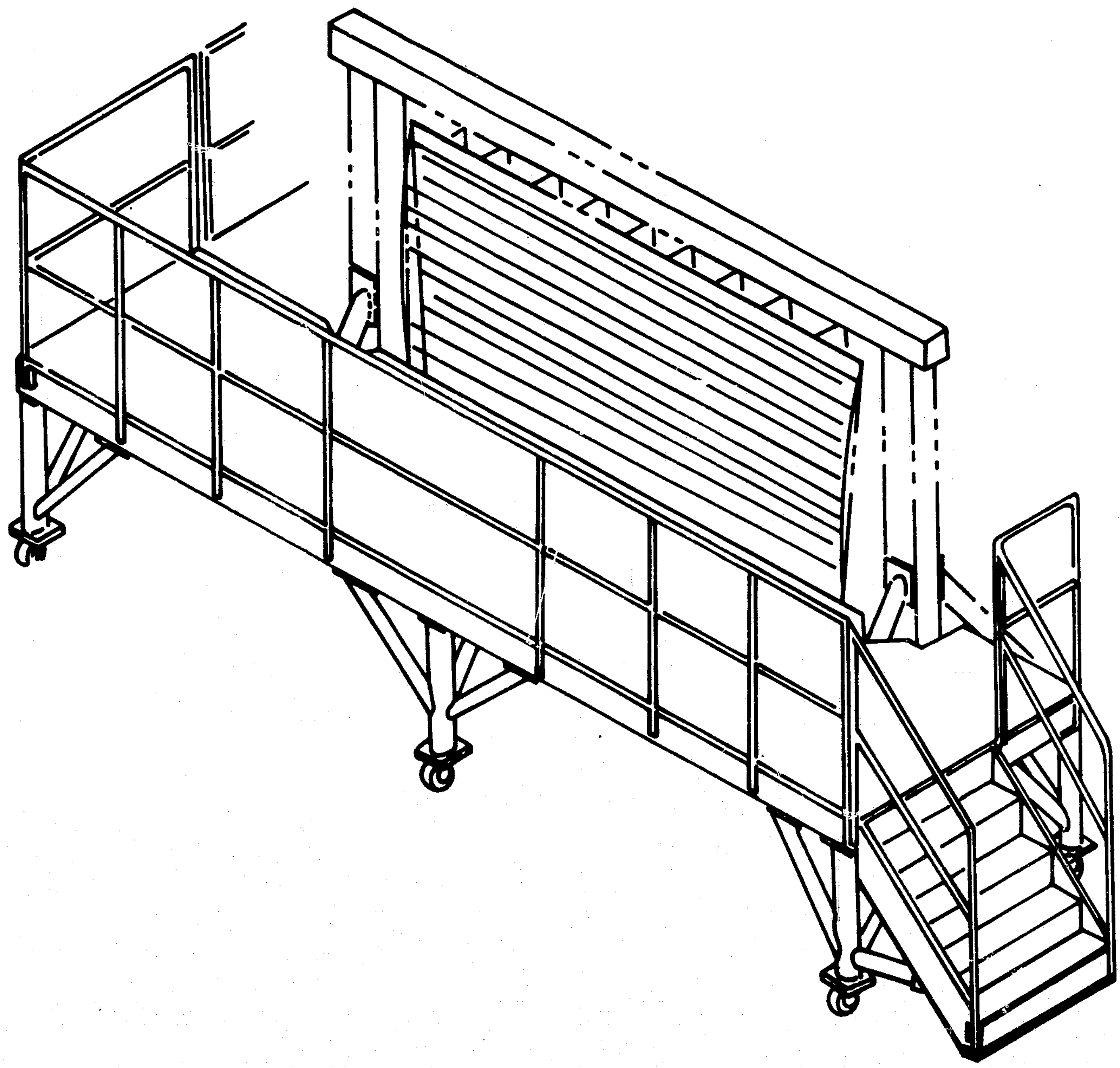


FIGURE 5.2.4.1-2 SKIN PANEL ASSEMBLY PERSONNEL PLATFORM

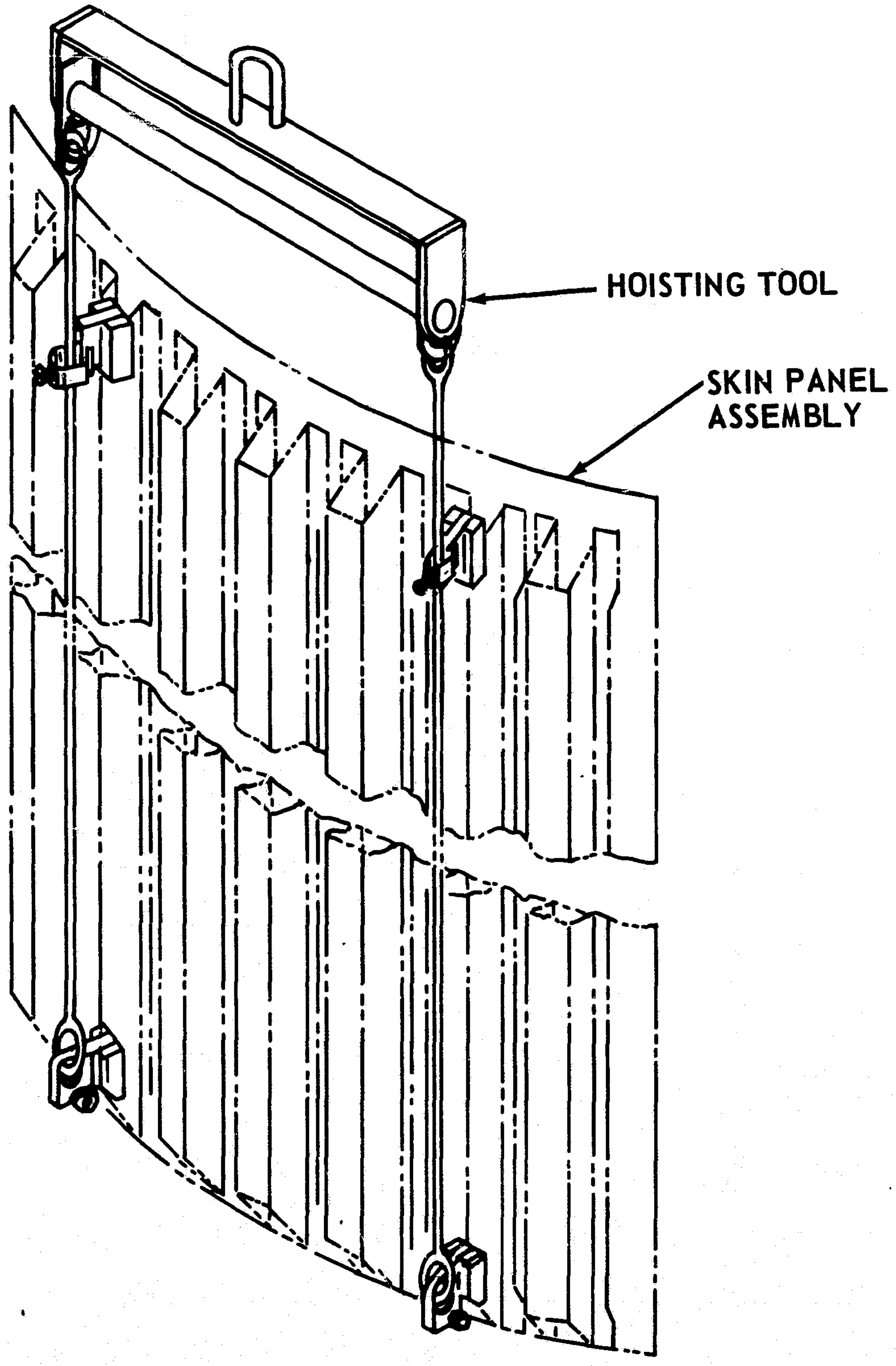


FIGURE 5.2.4.1-3 AFT SKIRT SKIN PANEL SUBASSEMBLY HOISTING TOOL

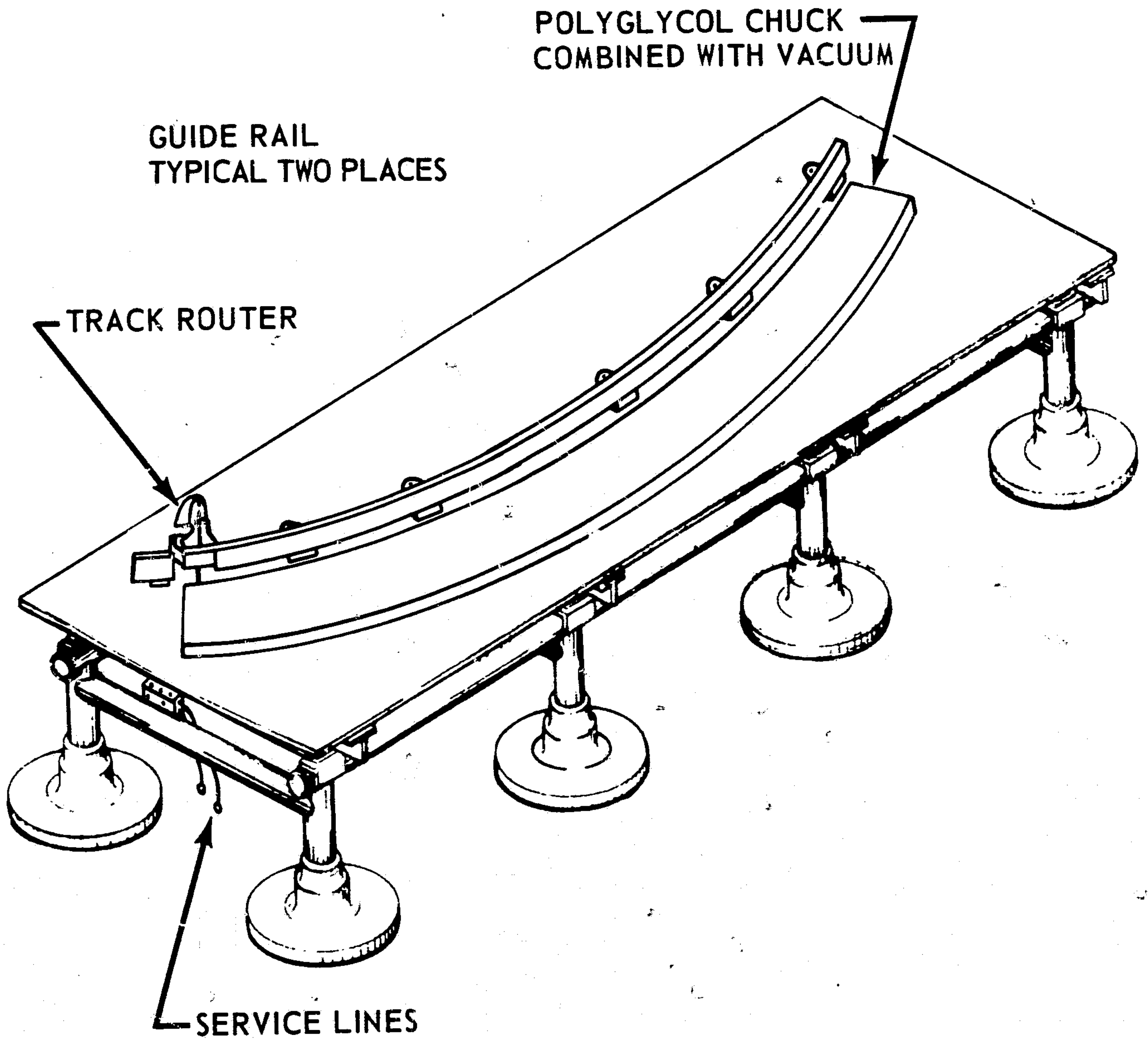


FIGURE 5.2.4.1-4 TRACK ROUTER TABLE WITH POLYGLYCOL CHUCK

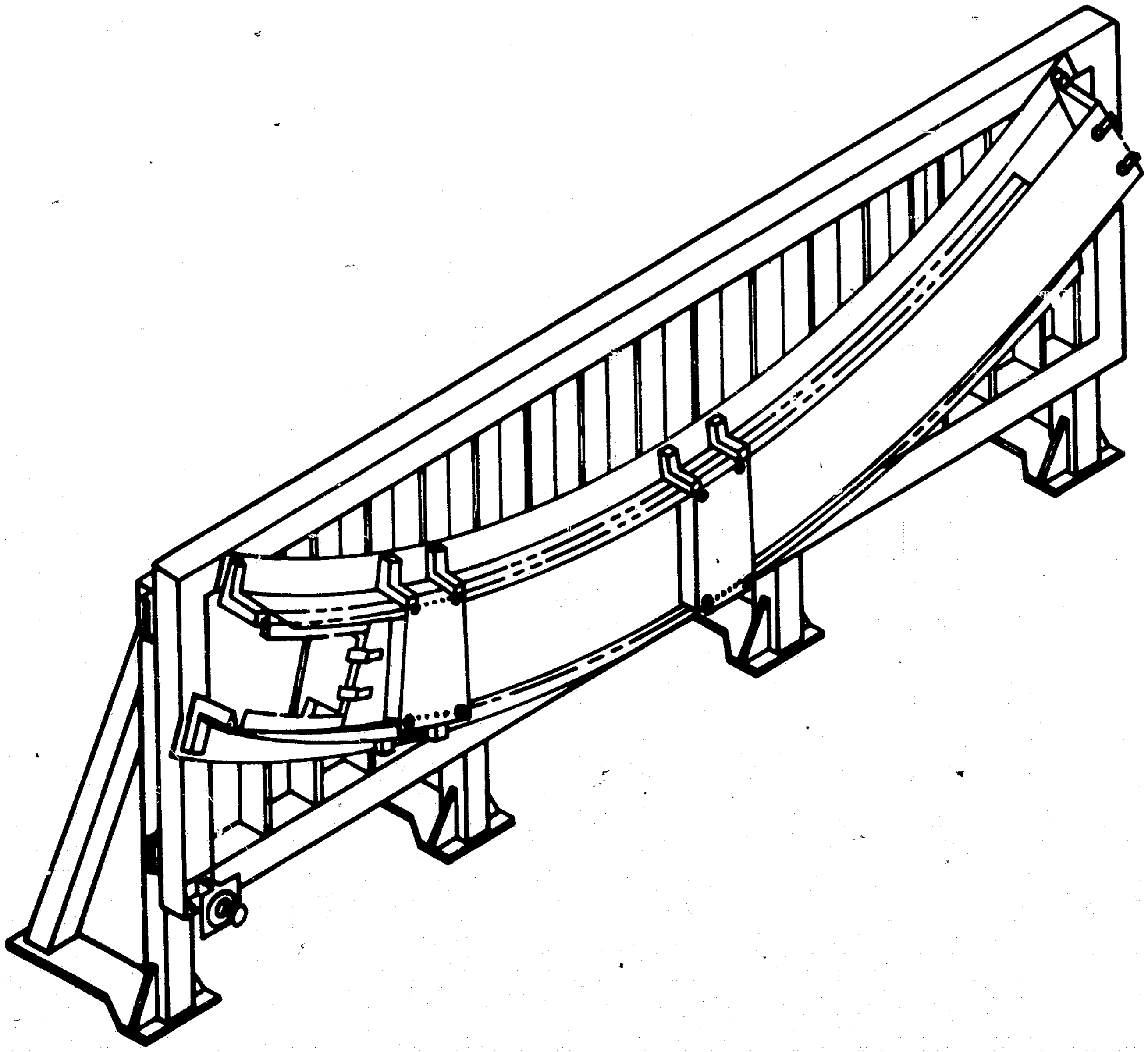


FIGURE 5.2.4.1-5 LOWER AND INTERMEDIATE RING ASSEMBLY FIXTURE

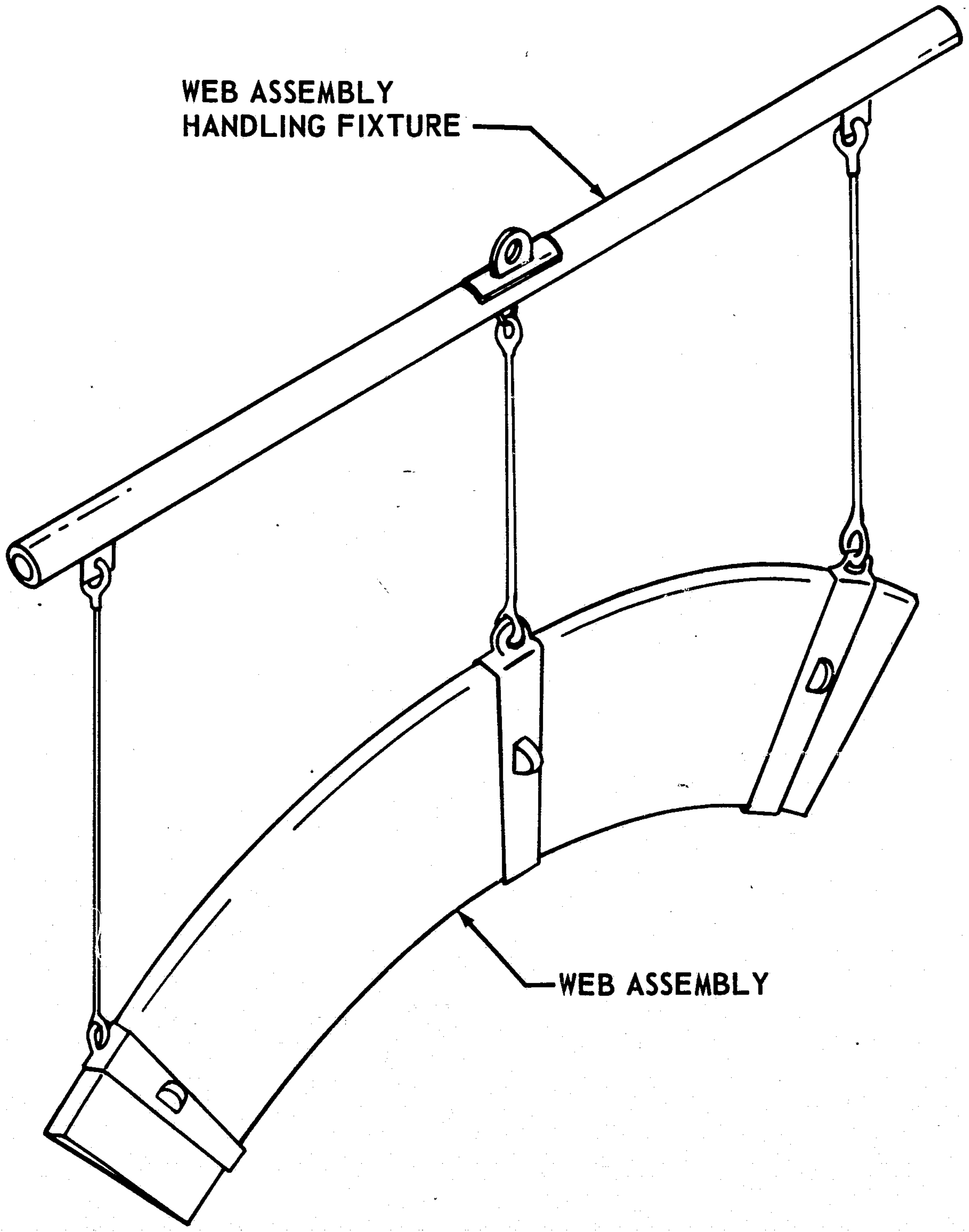


FIGURE 5.2.4.1-6 RING FRAME WEB ASSEMBLY HANDLING FIXTURE

5.2.4.1 (Continued)

ring segment) and other miscellaneous attachments. A vacuum bag placed over the face sheets provides the force necessary to assure a permanent bond. The entire assembly is then moved to the autoclave where the curing cycle is completed. When prescribed curing time has expired, the assembly is removed and allowed to cool. The honeycomb web is loaded into the segment assembly fixture, Figure 5.2.4.1-5. The honeycomb web is positioned and all attach holes are drilled, using drill plates and automatic air-feed drills.

When the attach holes are completed, parts are removed, deburred and replaced in the fixture. Only those fasteners that are common to the T-chords and web assembly are installed.

Rivets are touched-up with primer prior to removal to a transport/storage dolly. This assembly sequence is shown on Figure 5.2.4.1-7.

Engine Thrust Posts — The 24 thrust posts are each fabricated from a 7075-T6 aluminum forging on a NC milling machine. The finished thrust posts are cleaned, primed, and stored for future assembly in the final assembly jig.

Inner Splice-Plate — Each of the inner splice-plates is rolled to curvature from an aluminum forging, rough machined on a NC mill, heat treated, and machine finished to correct for distortion. When its dimensions are verified, the splice plate is degreased, cleaned, alodined, primed, and placed on a transport dolly. This manufacturing sequence is shown on Figure 5.2.4.1-8.

5.2.4.2 Aft Skirt Final Assembly

The aft skirt is assembled in the vertical upright position. This is accomplished in a fixture designed to provide complete support for the thrust-ring segments before they are joined with splice plates. This method eliminates the need for a separate assembly fixture and the associated transport equipment required to move the completed thrust ring to the core stage final assembly station.

The thrust-ring segments are loaded into the final assembly fixture. Drill plates are located over the splice-plate stations. A broken-arm drill is used to line bore the attach holes. The drill plates and splice plates are removed. Holes in the splice and ring segments are deburred and inspected prior to assembly with the required fasteners. The thrust posts and intermediate ring segments are loaded into the fixture. This procedure allows easy alignment relative to the thrust ring prior to final attachment. Optical checks will be made frequently during the assembly to assure proper alignment while building the structure.

Using the same tooling stations, the upper holding fixture for the intermediate-ring segments is removed and a dummy Y-ring is installed. This dummy ring provides an index line for locating the skin panels on the corresponding thrust posts. Assembly is completed by use of the above described procedures to locate, drill, unload, deburr,

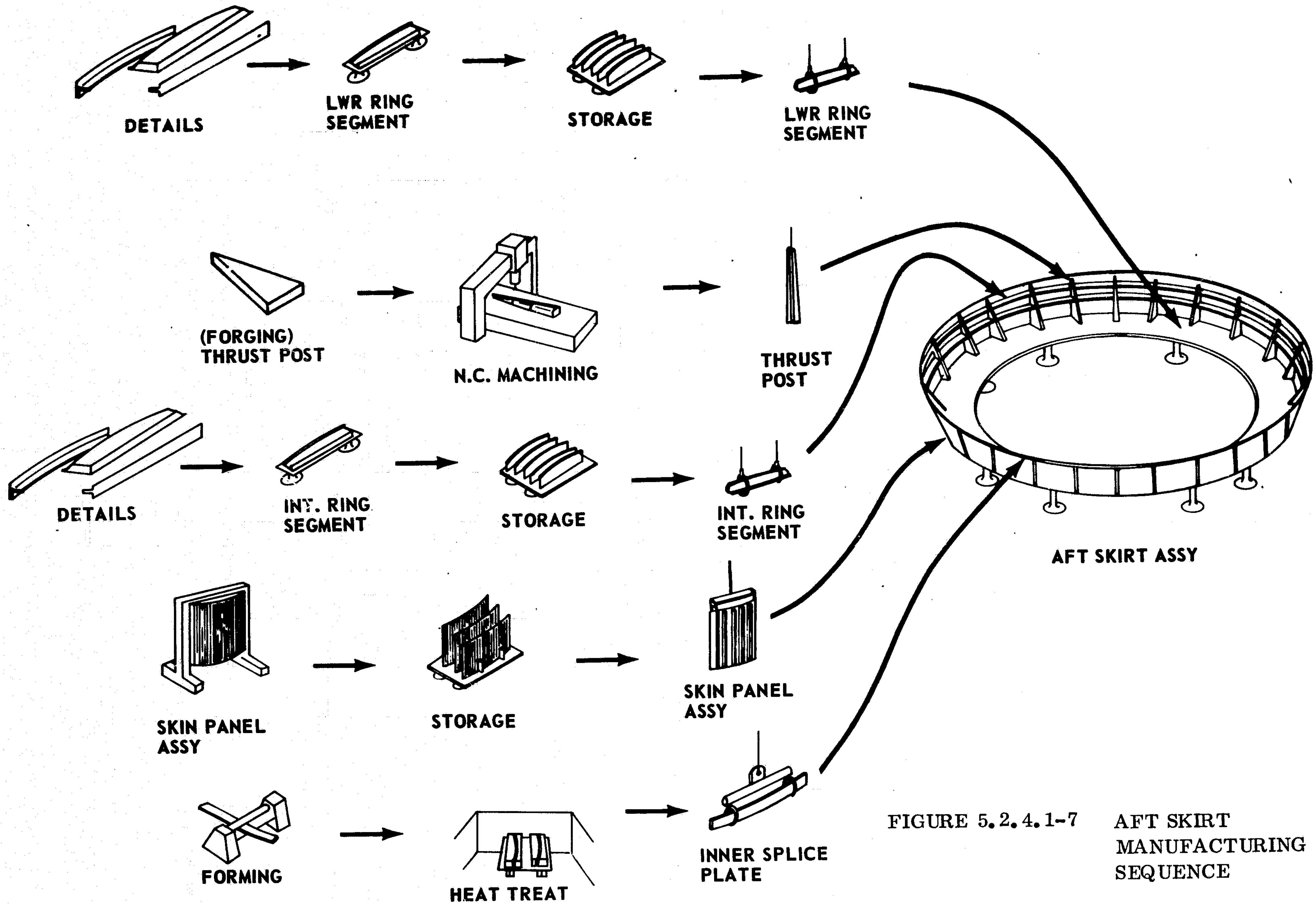


FIGURE 5.2.4.1-7 AFT SKIRT MANUFACTURING SEQUENCE

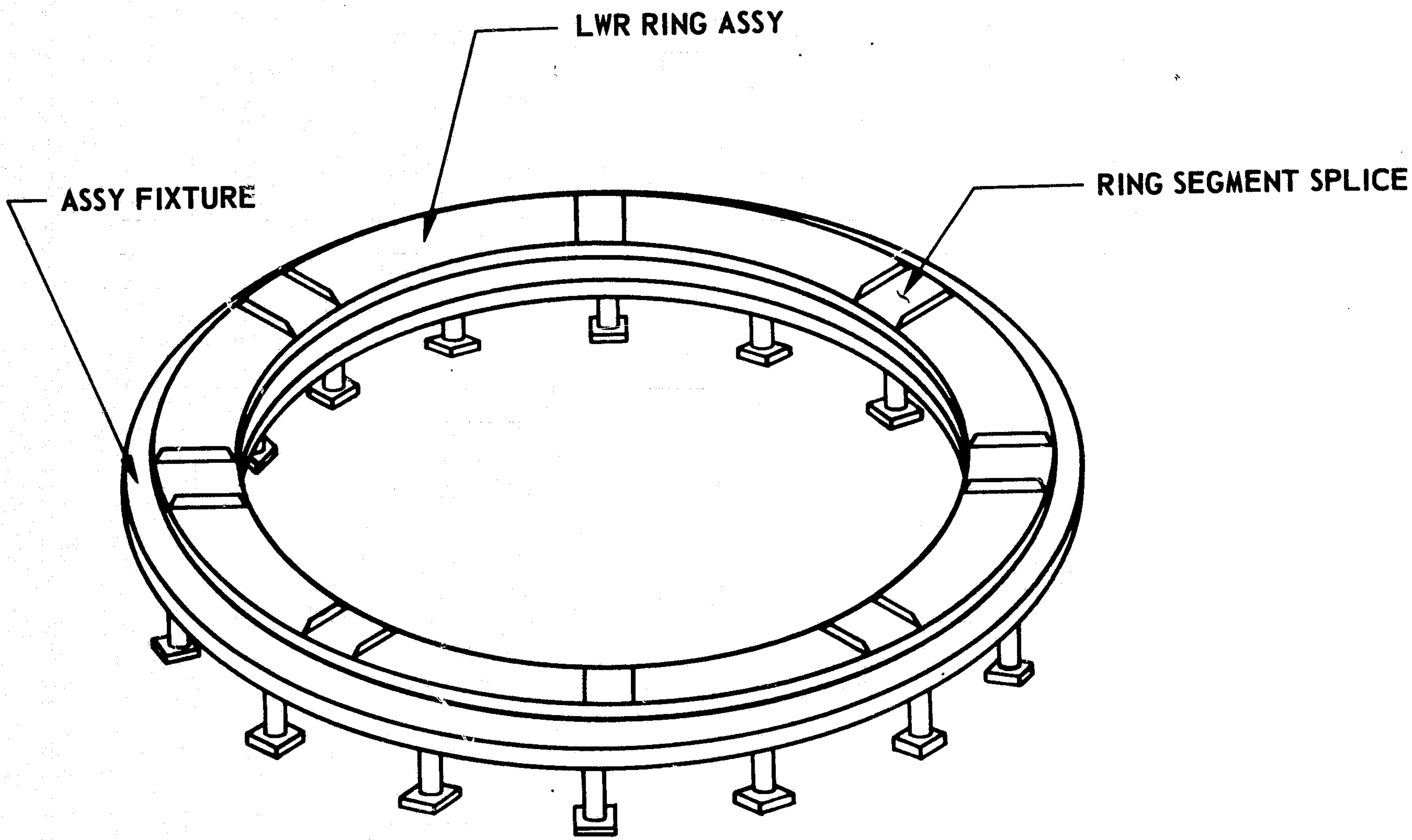


FIGURE 5.2.4.1-8 AFT SKIRT LOWER RING ASSEMBLY

5.2.4.2 (Continued)

reload, and fasten. Engine thrust fittings, gimbal post fittings, pressurization tanks, and miscellaneous brackets are then installed.

After all tooling has been removed and inspection is complete, the structure is raised with hydraulic jacks placed under alternate thrust post stations. The permanent supports are removed and replaced with transport dollies at several locations around the lower ring. The completed structure is then ready to be moved to the vertical assembly station where it will be mated with the lower bulkhead Y-ring.

5.2.5 Centerbody Plug

The centerbody plug is a conical structure with a base consisting of a stringer-sheet bulkhead. Two major assemblies make up the structure; the base plug (conic section structure) and the base bulkhead. The base plug is an aluminum honeycomb core structure with stainless steel inner and outer face-sheets. Regeneratively cooled tubes (Monel) are brazed to the outer face of the honeycomb structure. The tubes fit into upper and lower manifolds of the base plug. The lower manifold of the base plug mates with the 2219-T87 aluminum stringer-sheet base bulkhead. These two structures are mechanically fastened to form the complete center plug, Figure 5.2.5.0-1. Assembly steps are illustrated on Figure 5.2.5.0-2.

5.2.5.1 Centerbody Plug Subassemblies

The centerbody plug assembly is comprised of five subassemblies which are discussed in the following paragraphs.

Upper LH_2 Manifold — The upper LH_2 manifold consists of eight tubular segments. Each segment is of a tube and channel cross section. The segments are roll-formed to contour and the ends machined for welding. Each segment is then heat treated and subsequently placed in the manifold ring assembly fixture where the segments are welded and trimmed to the final configuration. The complete manifold ring is then moved to the outer-facing ring/manifold assembly fixture.

Lower LH_2 Manifold — The lower manifold assembly is fabricated in the same manner as the upper manifold. Eight segments are used to form the ring. The segments are fabricated by roll forming to contour. Each segment is heat treated and then placed in the lower manifold assembly fixture, aligned, clamped, and welded into the manifold ring. The welds are X-rayed and repaired as required. The manifold ring is then moved to the outer-facing skin-ring/manifold assembly fixture.

Outer Face-Skin Ring — The outer-facing ring is fabricated from 16 stainless steel preformed segments. The segments are cut from stainless stock sheet, bulge formed to contour and heat treated. After heat treatment, the formed trapezoidal segments are placed in a trimming fixture and cut to net size, Figure Figure 5.2.5.1-1. The segments are then positioned and clamped into the outer-facing ring assembly fixture for welding and final trimming operations, Figure 5.2.5.1-2. The structure is then transferred to the outer-facing ring/manifold assembly fixture.

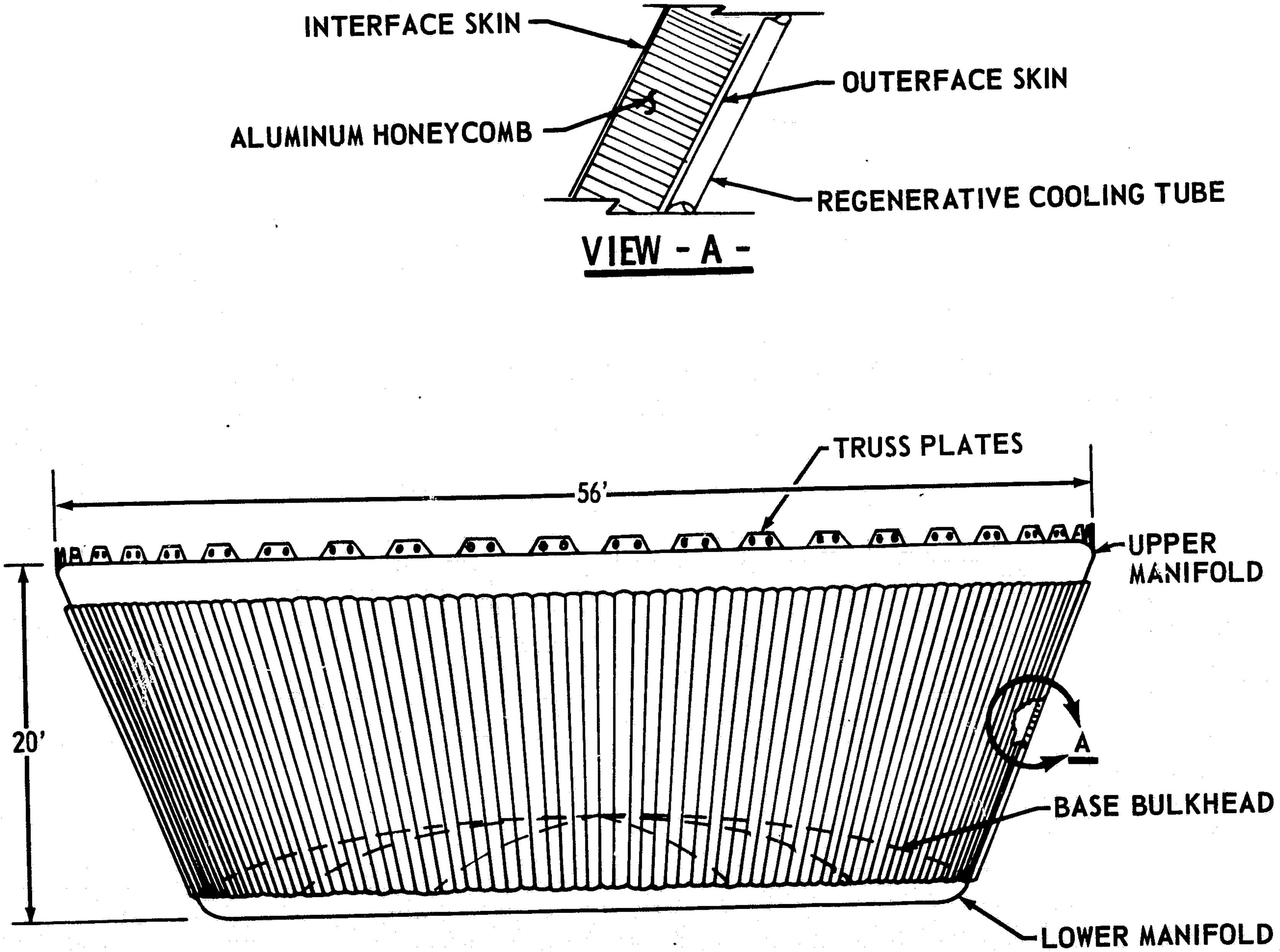


FIGURE 5.2.5.0-1 CENTERBODY PLUG ASSEMBLY

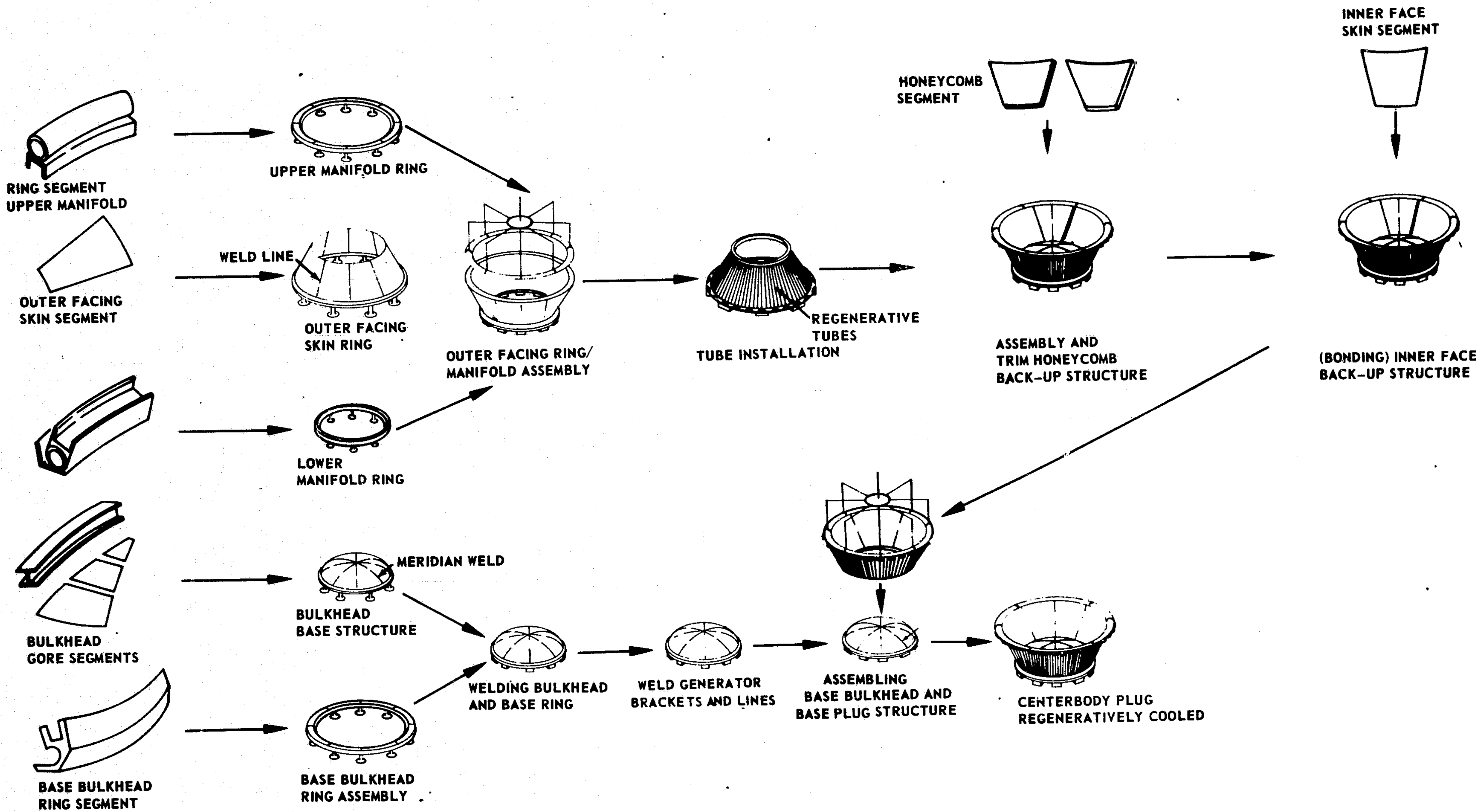


FIGURE 5.2.5.0-2 CENTERBODY PLUG ASSEMBLY SEQUENCE

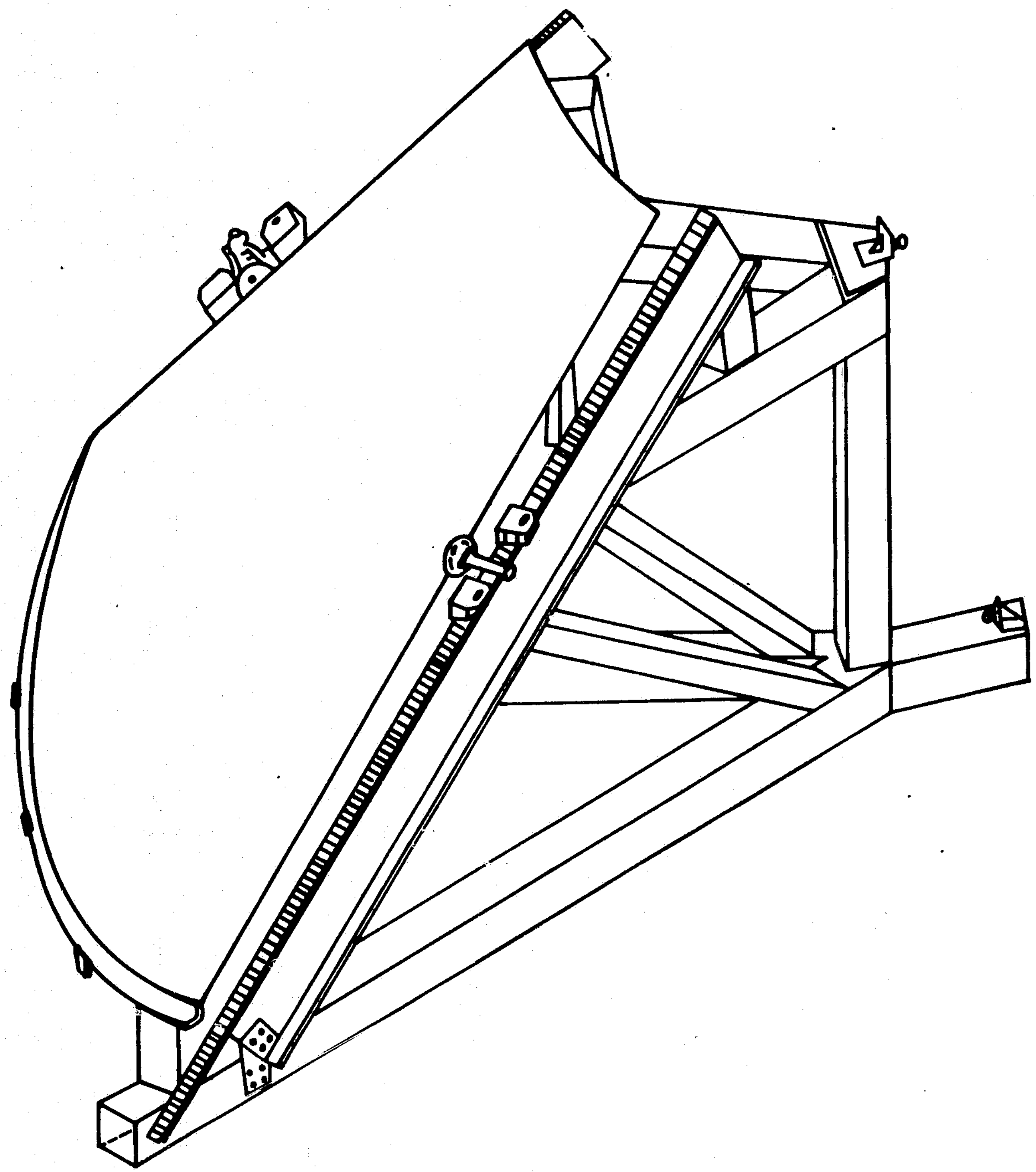


FIGURE 5.2.5.1-1. TRIM FIXTURE - INNER AND OUTER FACE SKIN SEGMENTS

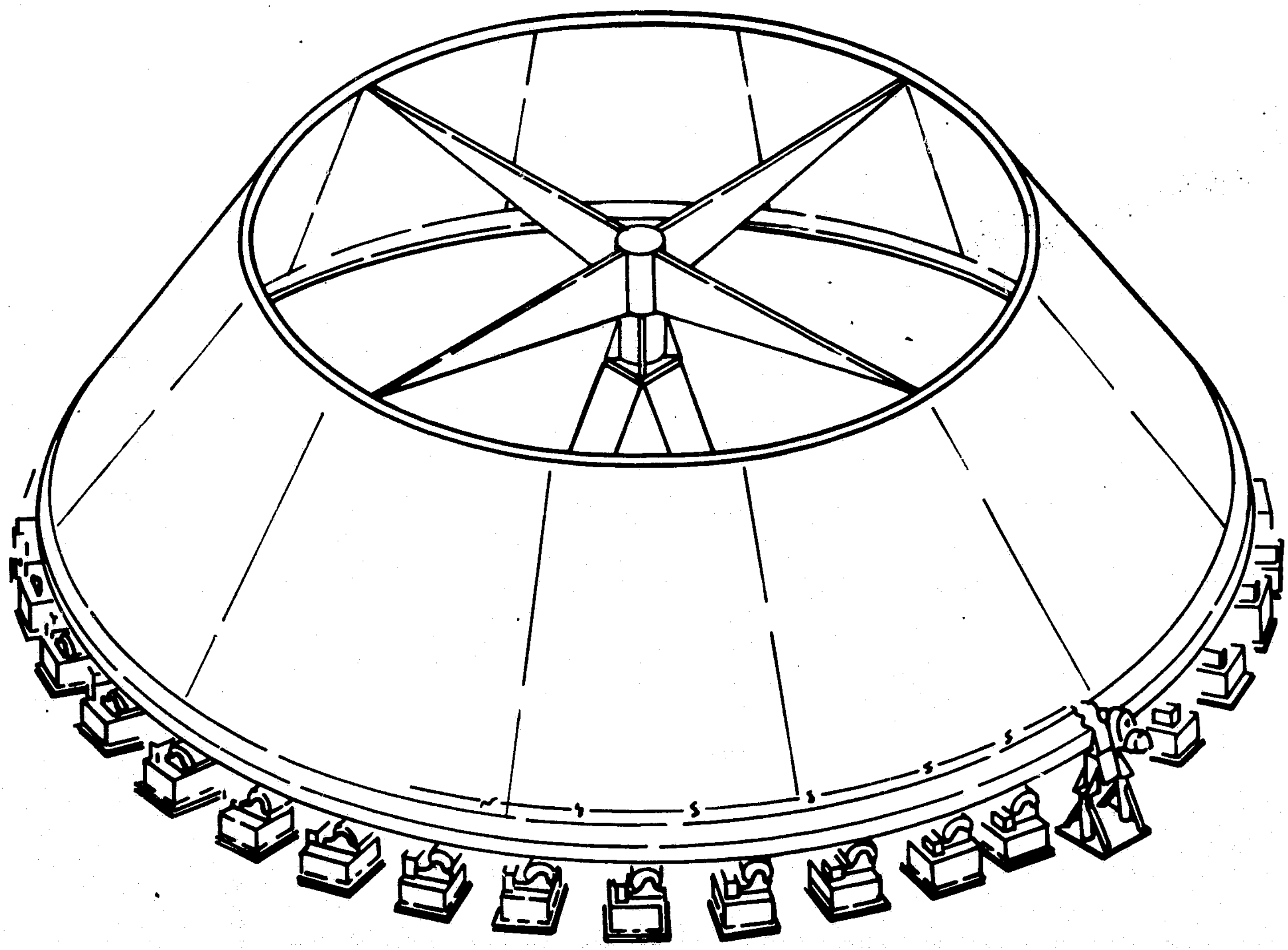


FIGURE 5.2.5.1-2 BASE PLUG - OUTER FACE SKIN RING WELD AND TRIM FIXTURE

5.2.5.1 (Continued)

Base Bulkhead Ring — The base bulkhead ring is constructed from eight roll-formed segments. Each segment is heat treated, cleaned, and placed in the bulkhead ring assembly fixture, where they are clamped, trimmed, and welded to the bulkhead ring configuration. The bulkhead ring remains in this fixture awaiting completion of the base structure bulkhead.

Base Structure Bulkhead — The base bulkhead consists of aluminum gore segments welded to an aluminum I-beam framework. The semielliptical structure is fabricated in the following manner. The gore sections are shaped to contour by the bulge forming method; each gore segment is heat treated; the gore sections are transferred to the trim fixture where they are positioned, clamped, and routed; after trimming, the gores are transferred to the bulkhead fabrication fixture for mating to the I-beam framework, Figure 5.2.5.1-3. The I-beam framework is constructed from rolled sections. The sections are heat treated, weld ends prepared and placed on the fabrication turntable for positioning and subsequent welding. The gore segments are then placed on this frame, positioned, clamped, and welded. All base panels are welded to the frame first, followed by the intermediate and apex panels. A center piece or polar cap is then lifted to the top of the bulkhead, positioned, clamped, and welded. This assembly is then transferred to the base bulkhead ring assembly fixture for mating with the bulkhead ring.

5.2.5.2 Centerbody Plug Final Assembly

The centerbody plug final assembly is accomplished according to the procedure in the following paragraphs:

Base Bulkhead Assembly — The base structure bulkhead and the base ring are assembled in the base-ring weld assembly fixture. The base structure bulkhead is lowered onto the base ring and aligned. The head assembly is welded to the bulkhead ring using the boom weld fixture. The weld is X-rayed and repaired where required. The brackets for the base plug gas generator and lines are also assembled and welded to the bulkhead at this station. The now complete base bulkhead is transferred to the base plug/base bulkhead final assembly fixture.

Base Plug Assembly, Outer Face-Ring/Manifold Assembly — The outer face-ring/manifold assembly consists of the upper and lower manifold rings and the outer-face skin ring for the backup structure. The lower manifold is placed on the assembly turntable and the outer-face skin ring is lowered into position. The mating surfaces are aligned, clamped, and welded using the boom weld fixture. The weld is X-rayed and repaired as required. The upper manifold ring is then lowered onto the outer-face skin ring. The skin ring and manifold are aligned, clamped, and welded. The welds are then X-rayed and repaired where required. The structure is inverted, Figure 5.2.5.2-1, and cleaned for installing the regenerative tube (Monel) assemblies. The tube assemblies are positioned, clamped, and induction brazed to the outer skin ring and manifold ports. The joints are checked and repaired as required. The assembly is then transferred to the backup structure assembly area.

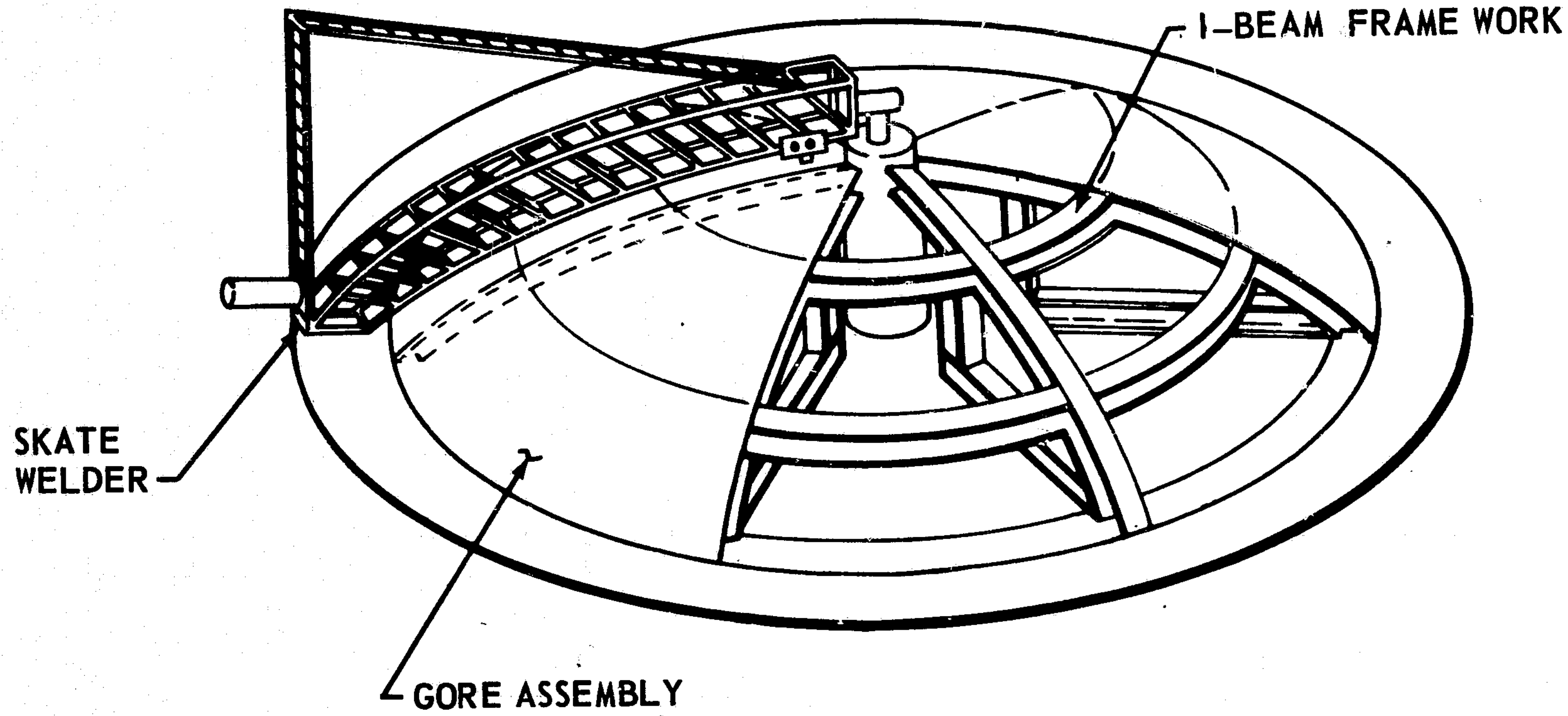


FIGURE 5.2.5.1-3 BASE STRUCTURE - BULKHEAD WELD FIXTURE

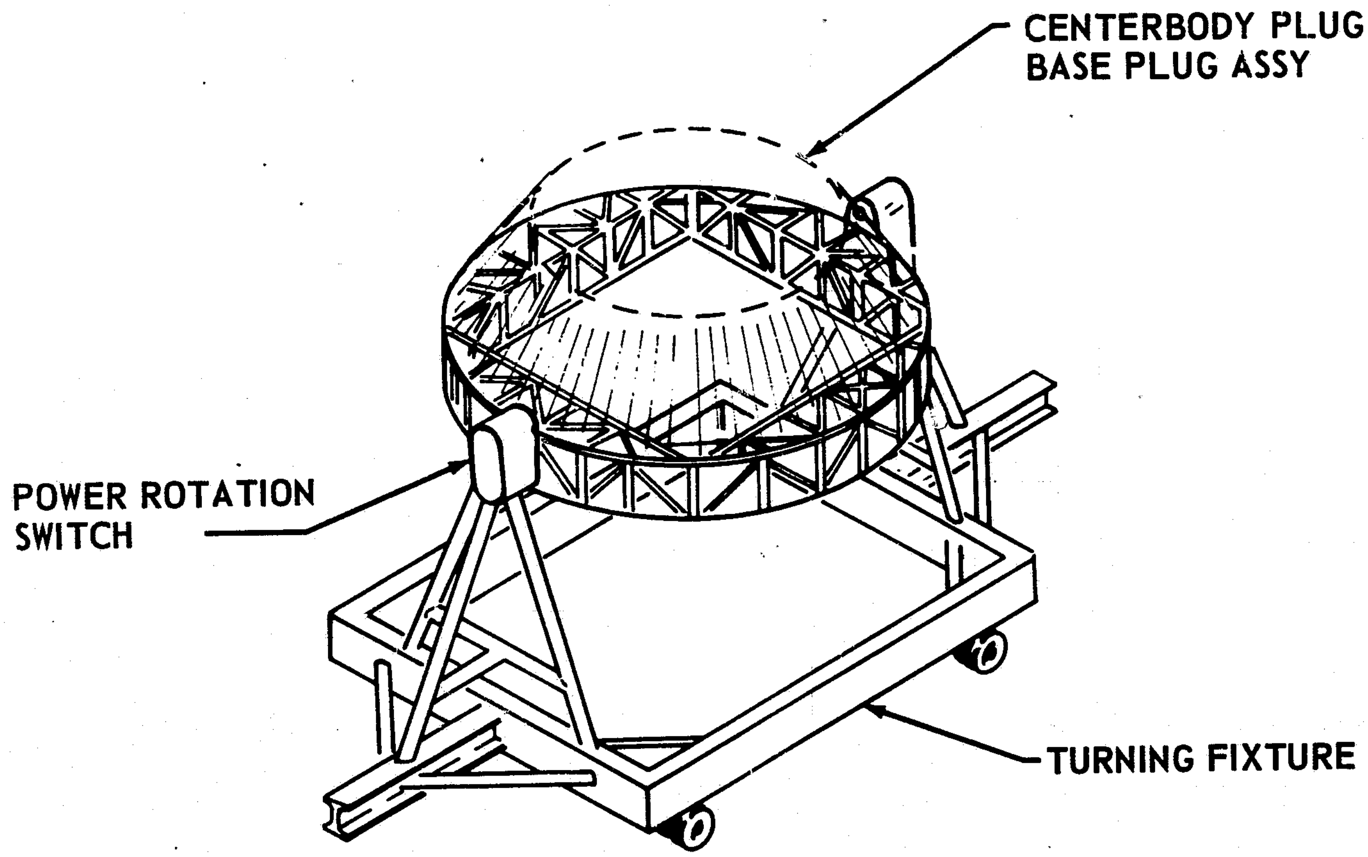


FIGURE 5.2.5.2-1 BASE PLUG INVERTING TOOL

5.2.5.2 (Continued)

Base Plug Assembly Backup Structure — Assembly consists of fitting the preformed aluminum honeycomb and inner-face skin sections to the inside surface of the outer-face ring/manifold assembly. The inside surface of the outer-face ring/manifold assembly is cleaned and prepared for adhesive bonding the honeycomb core panels. Sections of the honeycomb are laid up inside the skin ring. A holding frame is used to position and align the sections. The bonded sections are then vacuum bagged and cured individually in an autoclave. The section joints are then joined by bonding doublers over the joints. The bonds are checked and repaired as required. Next, the assembly is transferred to the final assembly station for mating with the base bulkhead.

Base Bulkhead, Base Plug Assembly — Final assembly operations consist of joining the base bulkhead with the base plug structure. The complete base bulkhead assembly is lowered onto the assembly fixture, aligned, and clamped in the fixture. The base conical structure is then lowered to the mating position on the bulkhead, and mechanically fastened to the lower manifold ring of the base plug structure. The truss plates for the tubular trusswork are then located and welded to the upper manifold ring. The completed centerbody plug is mechanically attached to the tubular trusswork and aft skirt in the VAB (Figure 5.2.3.1-1) during final assembly.

5.2.6 Main Stage, Final Assembly

The final assembly operation consists of mating the major structural assemblies to the core stage configuration and installing the propulsion and electrical system components on the stage. The structural assemblies, with the exception of the centerbody plug and engines, will be assembled with the stage in a vertical position. All other systems installations will be accomplished horizontally. In assembling a structure of this size, the number of operations and concurrently the number of tools becomes a major factor in arriving at the most cost-effective assembly procedure. The method described herein is designed to use a minimum number of major tools.

The assembly sequence procedure is shown on Figure 5.2.6.0-1 (3 sheets) and is accomplished as described below:

5.2.6.1 Forward Skirt, Propellant Tank Assembly

The forward skirt assembly (which has been previously fabricated, complete with all internal components installed, finish primed, and stored), is moved to the final assembly location in the vertical assembly building (VAB). Utilizing the forward handling ring, Figure 5.2.6.1-1, the forward skirt is hoisted above the tank assembly tower and positioned above the upper LOX bulkhead (Station 1454). Alignment of the skirt and the bulkhead is accomplished with a tool similar to the one shown on Figure 5.2.6.1-2. Adjustments of the vertical alignment are made with a tool as shown on Figure 5.2.6.1-3. This vertical adjustor is capable of being positioned at several locations around the circumference of the upper LOX tank Y-ring. A method for checking axial alignment is shown on Figure 5.2.6.1-4. Where proper alignment is assured, a drill jig, Figure 5.2.6.1-5, is positioned, and all fastener holes are drilled and reamed to the proper size.

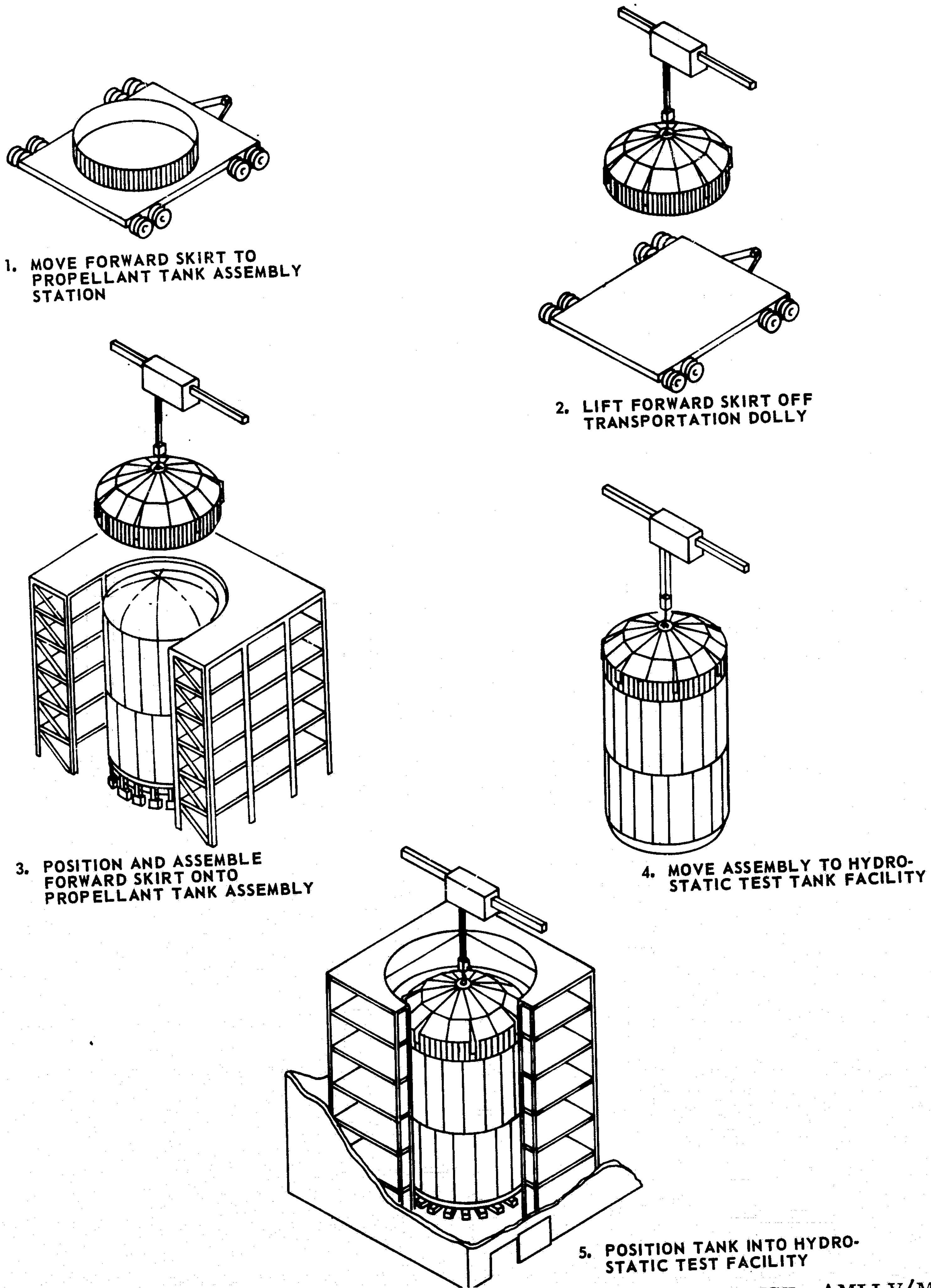
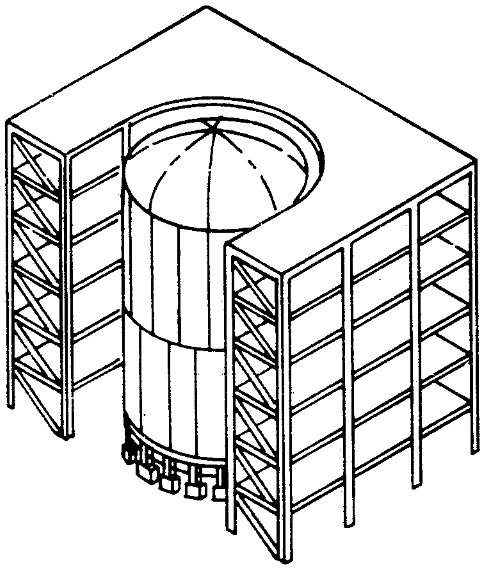
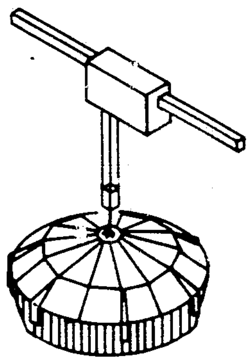


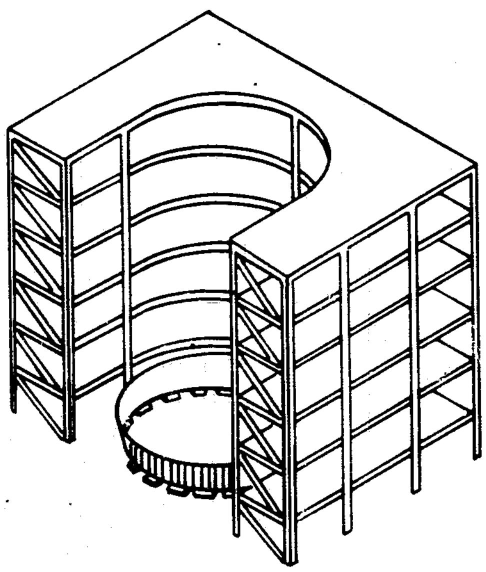
FIGURE 5.2.6.0-1 (Sheet 1 of 3). COMPLETE MANUFACTURING SEQUENCE, AMLLV/MLLV



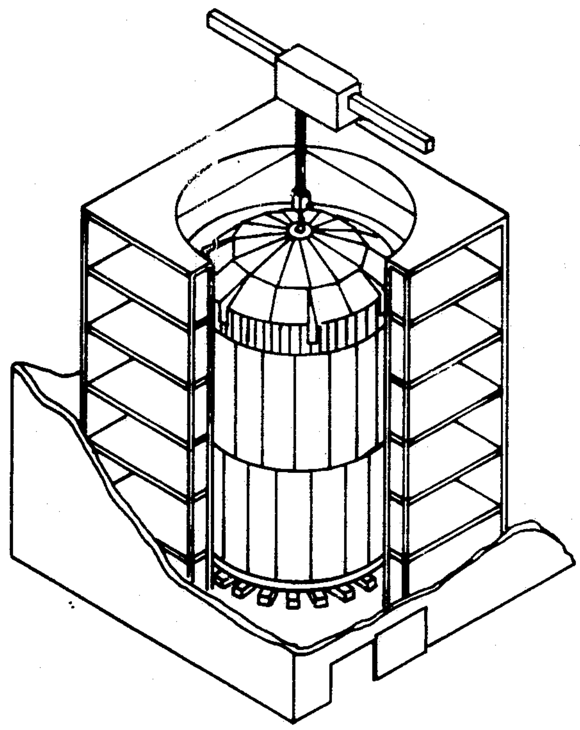
6. CLEAN AND HYDROSTATIC TEST TANKS



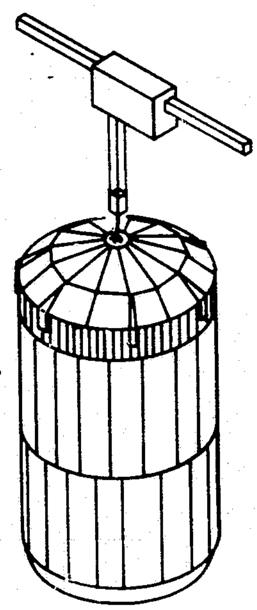
7. MOVE AFT SKIRT ASSEMBLY TO PROPELLANT TANK ASSEMBLY STATION



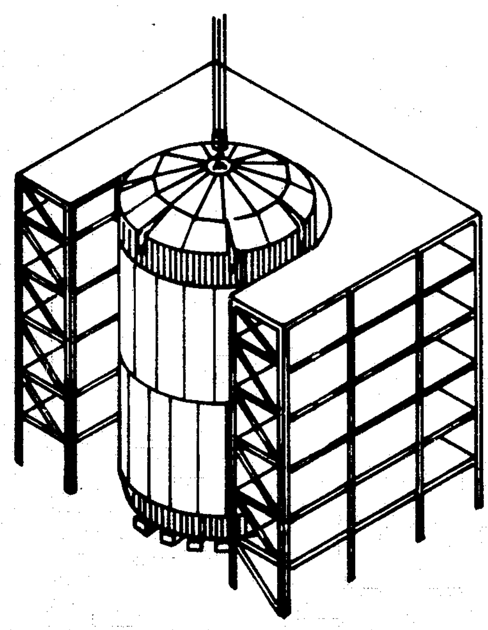
8. POSITION AFT SKIRT IN ASSEMBLY TOWER



9. REMOVE PROPELLANT TANK ASSEMBLY FROM HYDROSTATIC TEST FACILITY



10. TRANSPORT PROPELLANT TANK FROM HYDROSTATIC TOWER TO TANK ASSEMBLY STATION



11. POSITION PROPELLANT TANK ON AFT SKIRT ASSEMBLY AND MECHANICALLY FASTEN

FIGURE 5.2.6.0-1 (Sheet 2 of 3). COMPLETE MANUFACTURING SEQUENCE, AMLLV/MLLV

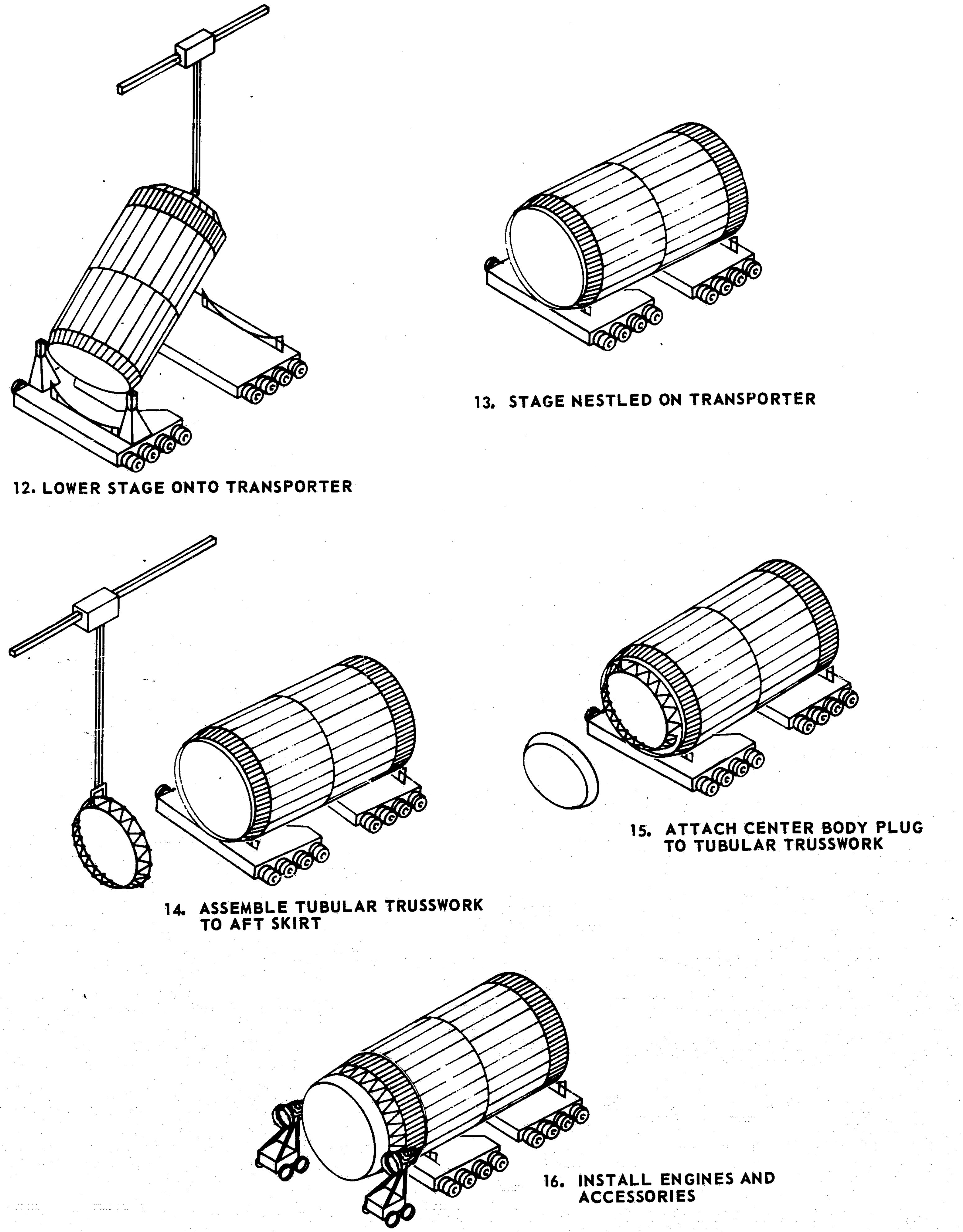


FIGURE 5.2.6.0-1 (Sheet 3 of 3) COMPLETE MANUFACTURING SEQUENCE, AMLLV/MLLV

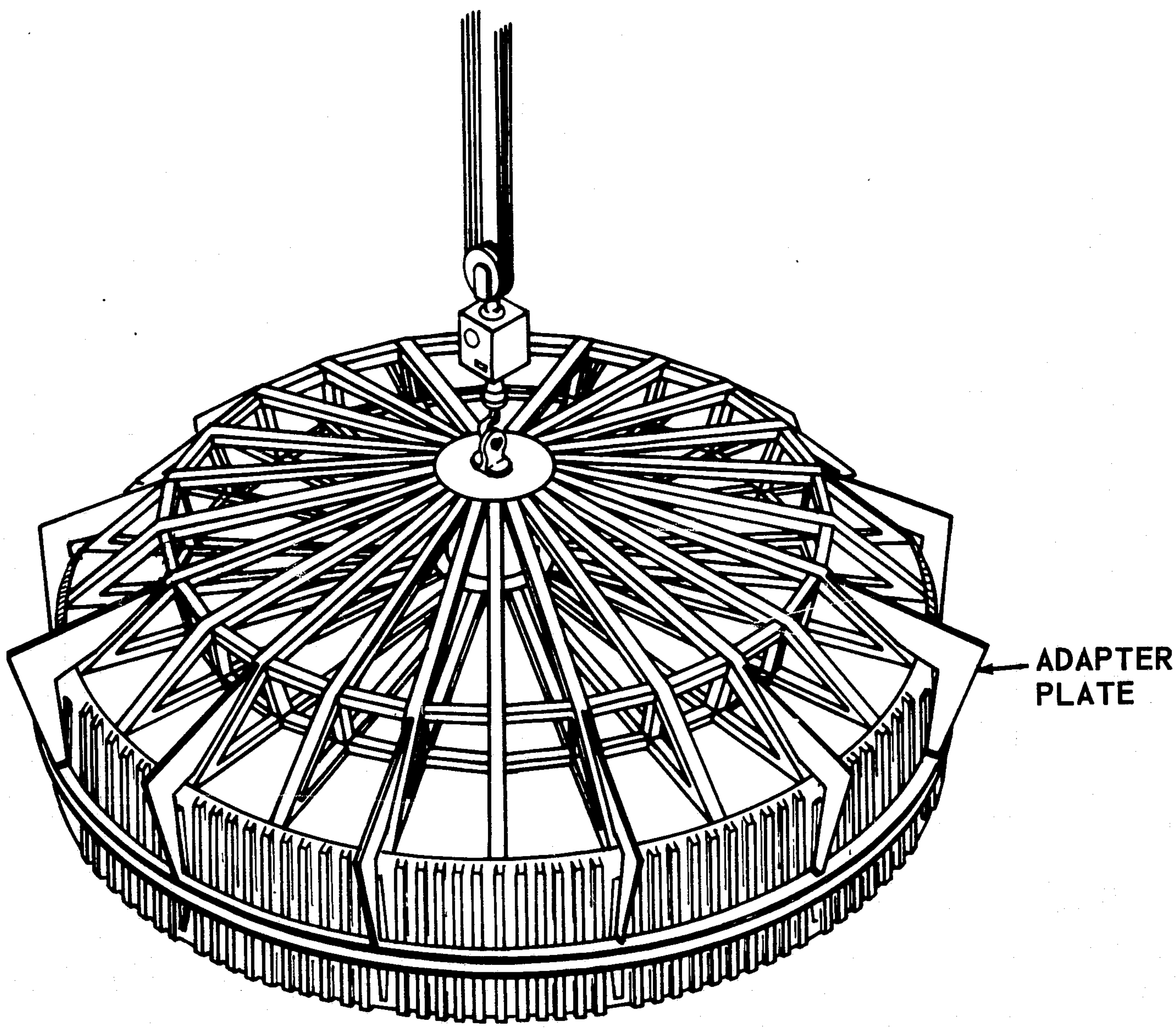


FIGURE 5.2.6.1-1 FORWARD HANDLING RING AND FORWARD SKIRT ADAPTERS

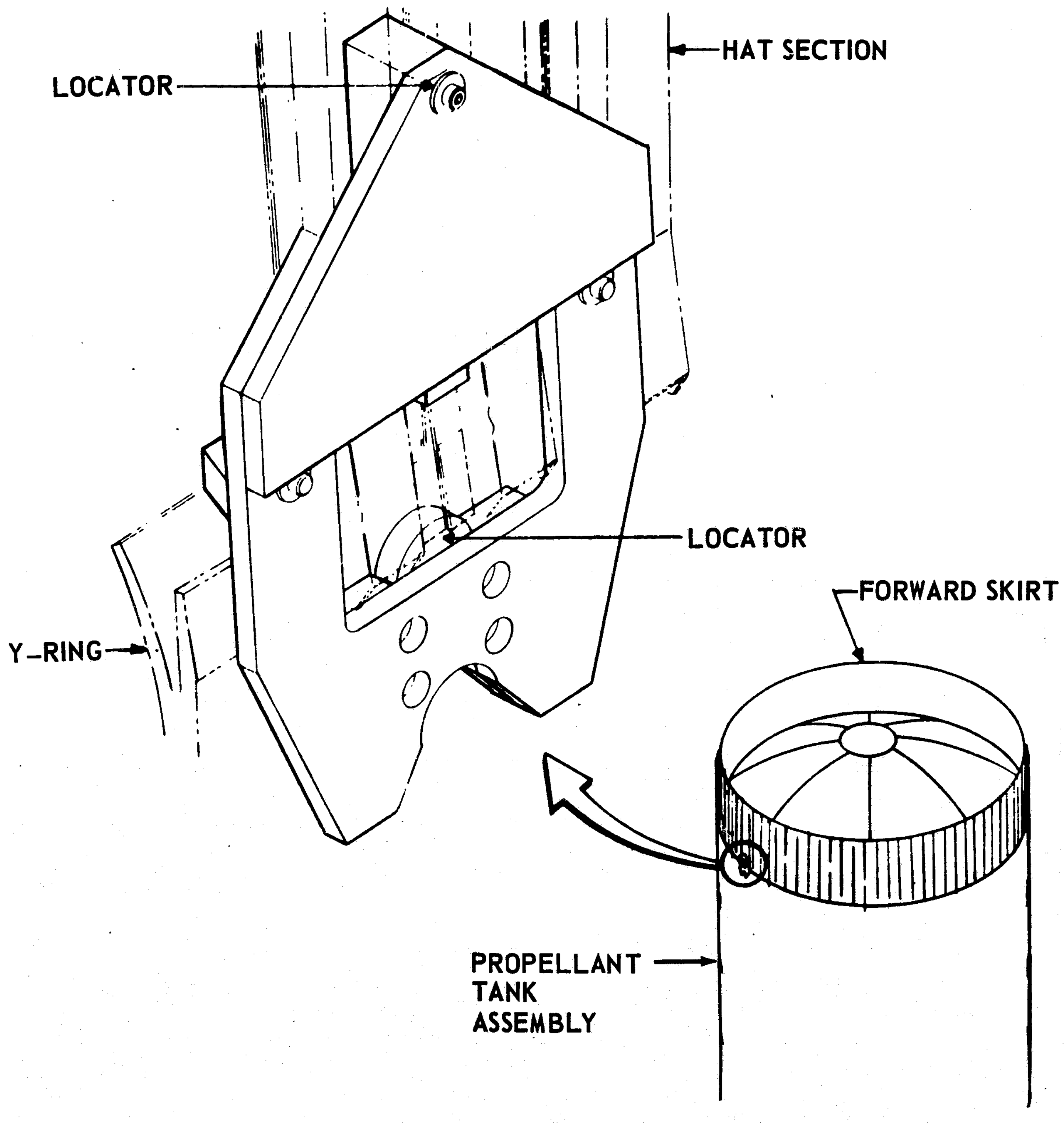


FIGURE 5.2.6.1-2 FORWARD SKIRT RADIAL ALIGNMENT TOOL

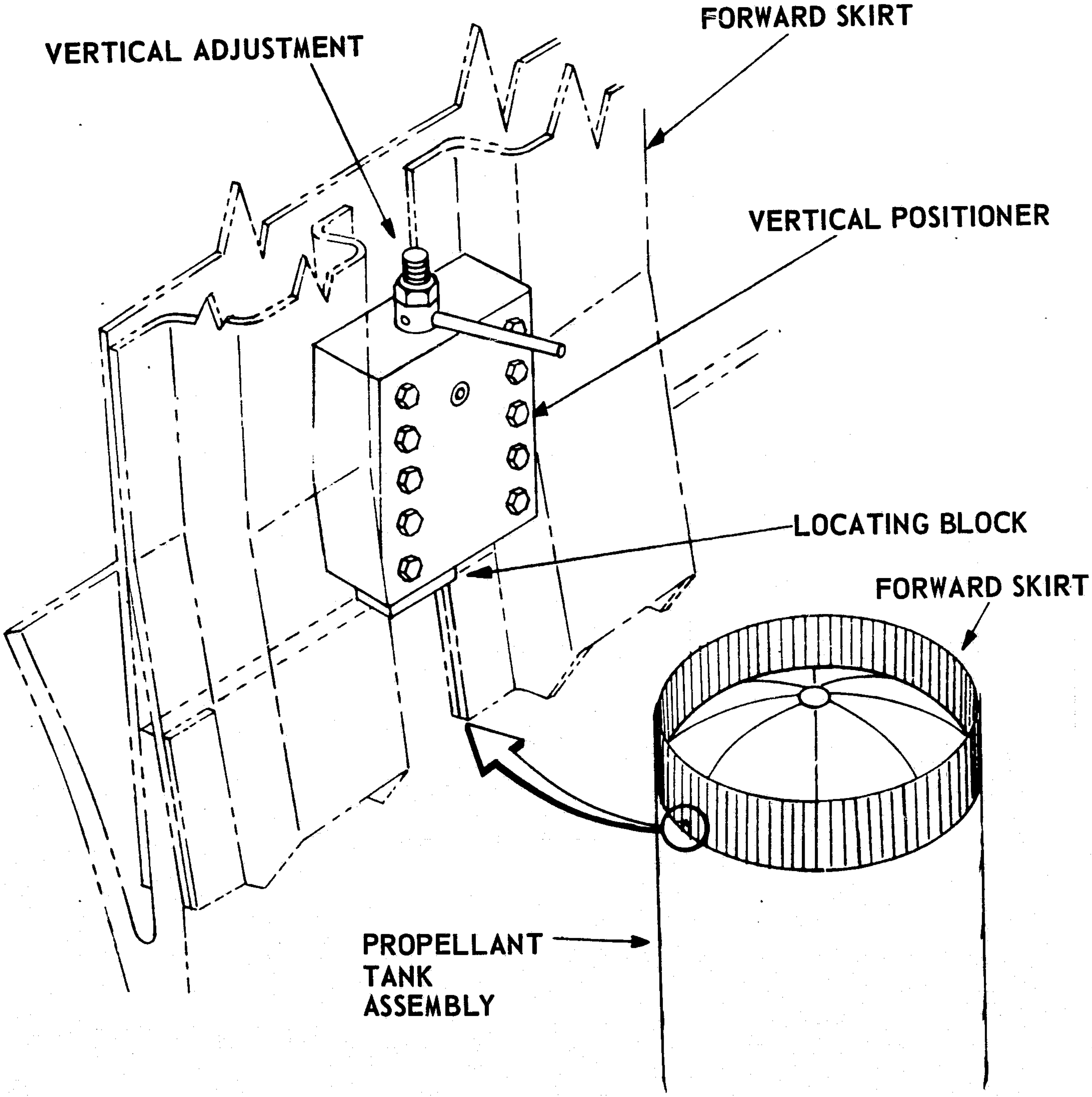


FIGURE 5.2.6.1-3 FORWARD SKIRT VERTICAL POSITIONERS

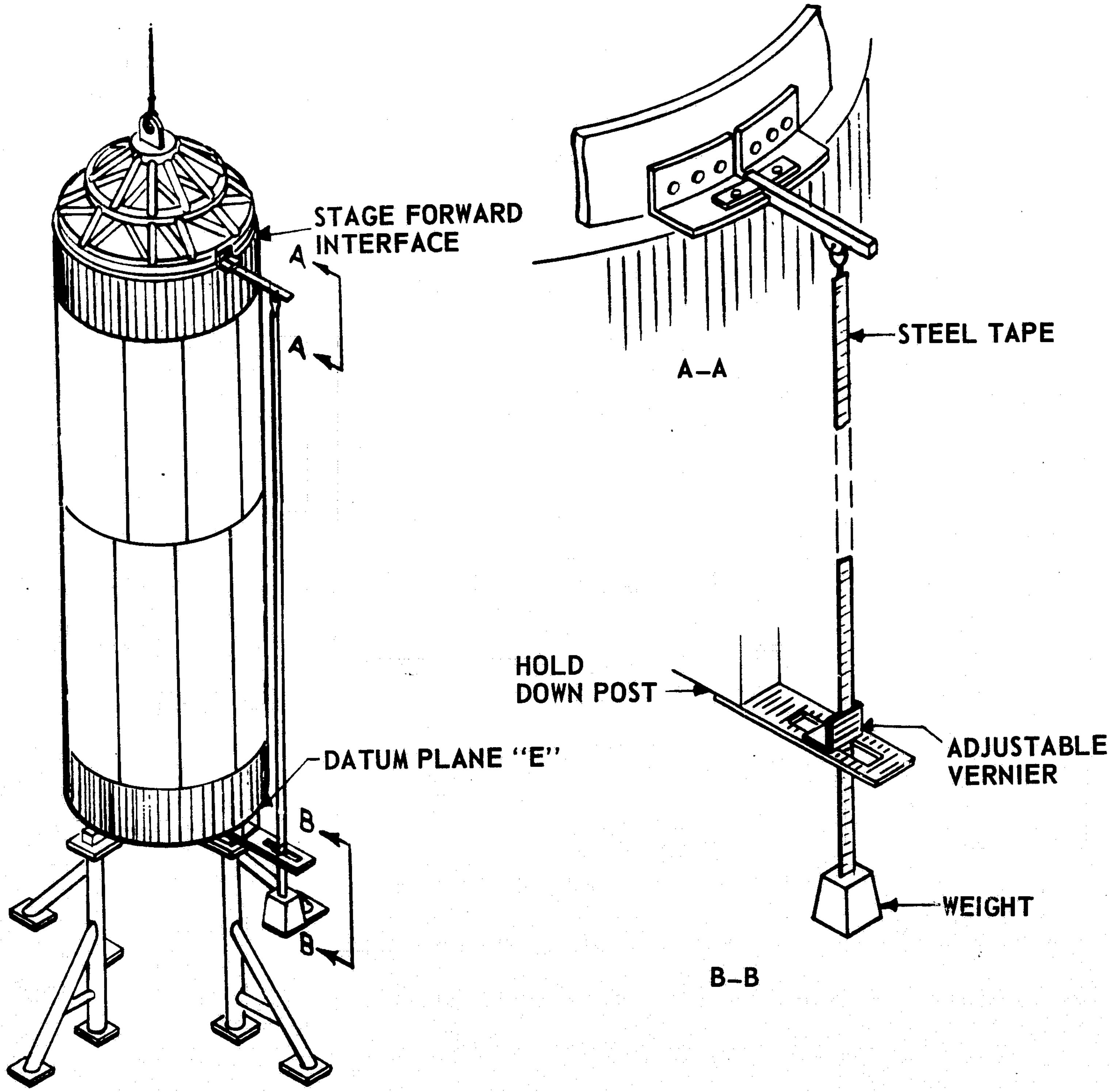


FIGURE 5.2.6.1-4 CHECKING PARALLELISM BETWEEN DATUM PLANE E AND STAGE FORWARD INTERFACE

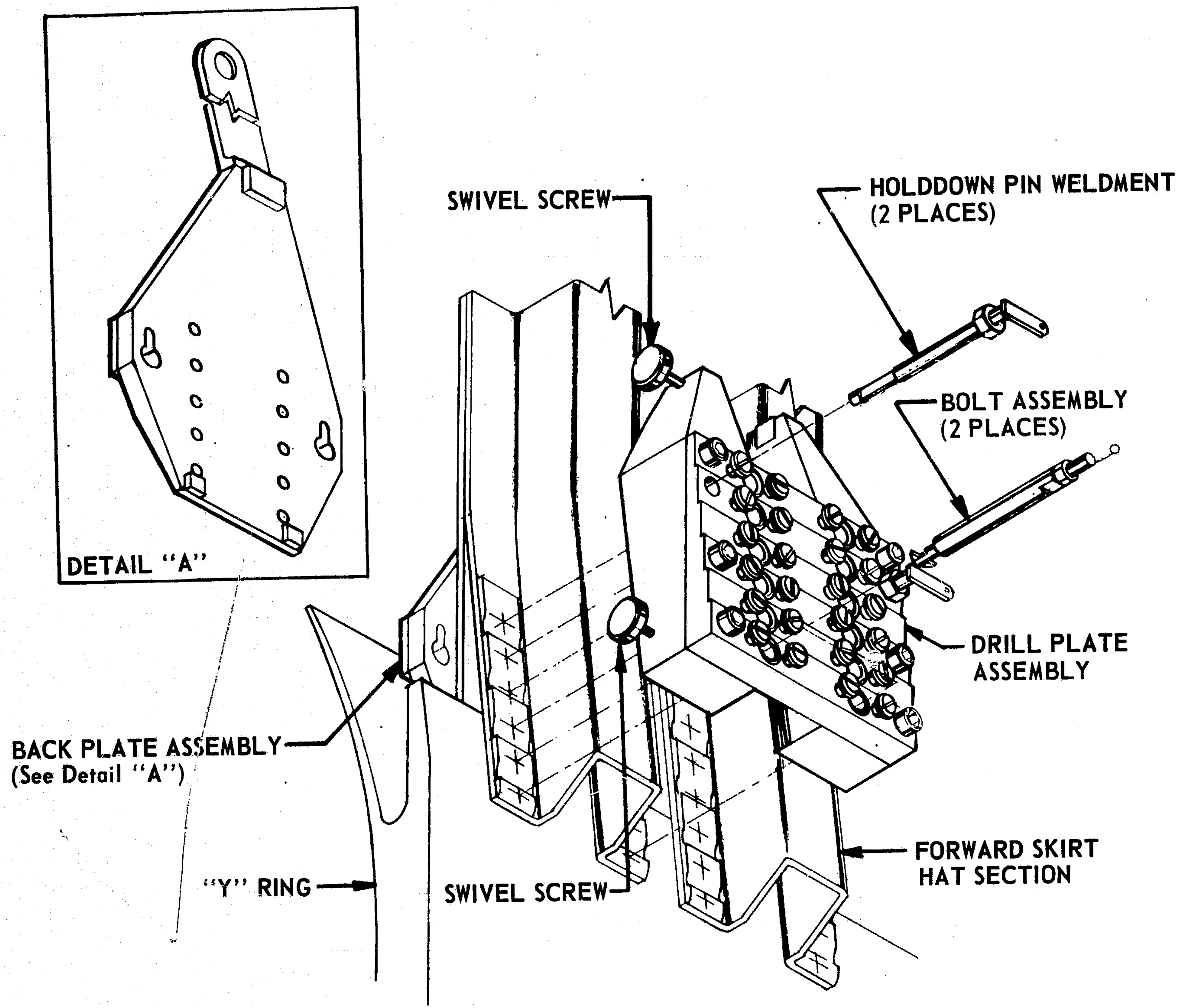


FIGURE 5.2.6.1-5 FORWARD SKIRT DRILL JIG

5.2.6.1 (Continued)

The forward skirt is raised to allow access to the inside surface for hole deburring and final inspection. When this operation is complete, the skirt is lowered, re-aligned, and fasteners are installed.

The forward skirt/tank assembly is then hoisted from the assembly tower and placed in the hydrostatic tank station where the tank integrity is verified.

5.2.6.2 Aft Skirt, Propellant Tank, Forward Skirt Assembly

Once the forward skirt/tank assembly is in position in the hydrostatic test area, the forward handling ring is removed. A circumferential ring is attached to the SRM aft attachment backup fittings and the aft slipjoint fittings. This ring will remain attached and will serve as a multipurpose tool throughout final assembly. When the attachment is complete, the forward handling ring with appropriate adapter plates is fastened to the top of the circumferential ring. The aft skirt is then positioned in the vertical assembly fixture. Primary support consists of rollers that bear against the bottom of the circumferential ring. The handling ring adapters are removed, and the handling ring is lifted away, Figure 5.2.6.2-1.

A rack is positioned atop the circumferential ring. Four integral drive motor/transmissions engage the rack from stands located on the side of the aft skirt supports.

This arrangement enables complete rotation of the tank assembly, Figure 5.2.6.2-2. To properly locate the top of the aft skirt relative to the propellant tank aft Y-ring, vertical positioners, Figure 5.2.6.2-3, are installed at 24 places along with 24 rotational positions, Figure 5.2.6.2-4. Existing tooling points located at the top of the hat sections will be utilized to position these tools.

When hydrostatic test of the tank assembly is complete, the forward handling ring, with the appropriate adapter plate, is attached to the forward skirt. The forward skirt-tank assembly is then hoisted from the hydrostatic station and positioned on the aft skirt. Drill jigs and backup plates are installed, Figure 5.2.6.2-5. Automatic air actuated drill motors are used to drill and ream fastener holes. When this operation is complete, the forward skirt-tank assembly is removed, the holes are deburred, and the tank is repositioned on the aft skirt. When these components are aligned, the fasteners are installed.

5.2.6.3 Tank Insulation

A description of the procedure for applying polyurethane foam to the tank forms follows. The access covers are masked with a resistant material, and polyurethane sheets are taped around the top of the forward and aft skirts to prevent liquids from running into the hot sections.

Using a rotary brush mechanism on a vertical track, the tank surface is etched with a solution of sodium dichromate and sulphuric acid.

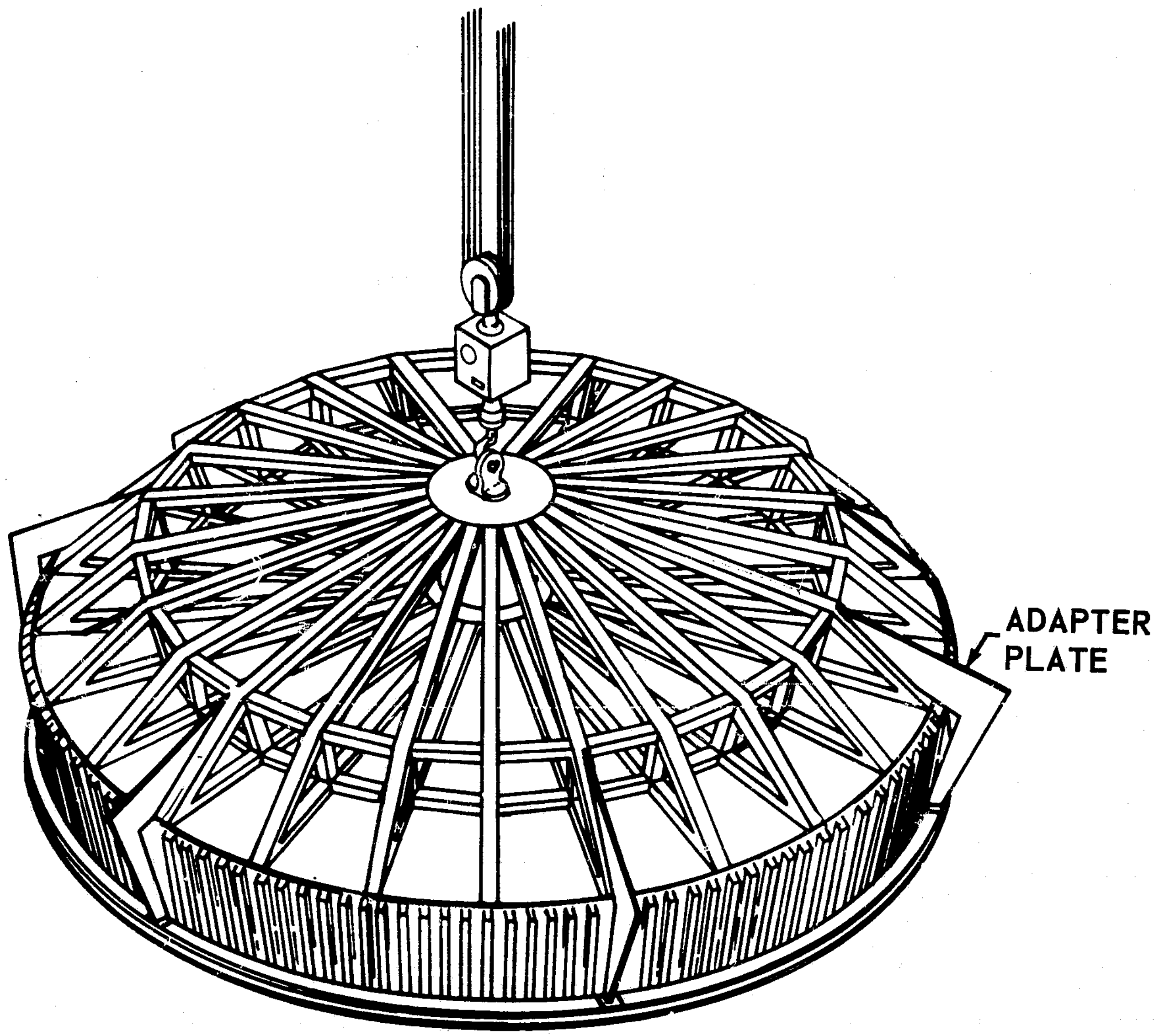


FIGURE 5.2.6.2-1 FORWARD HANDLING RING ADAPTED TO AFT SKIRT

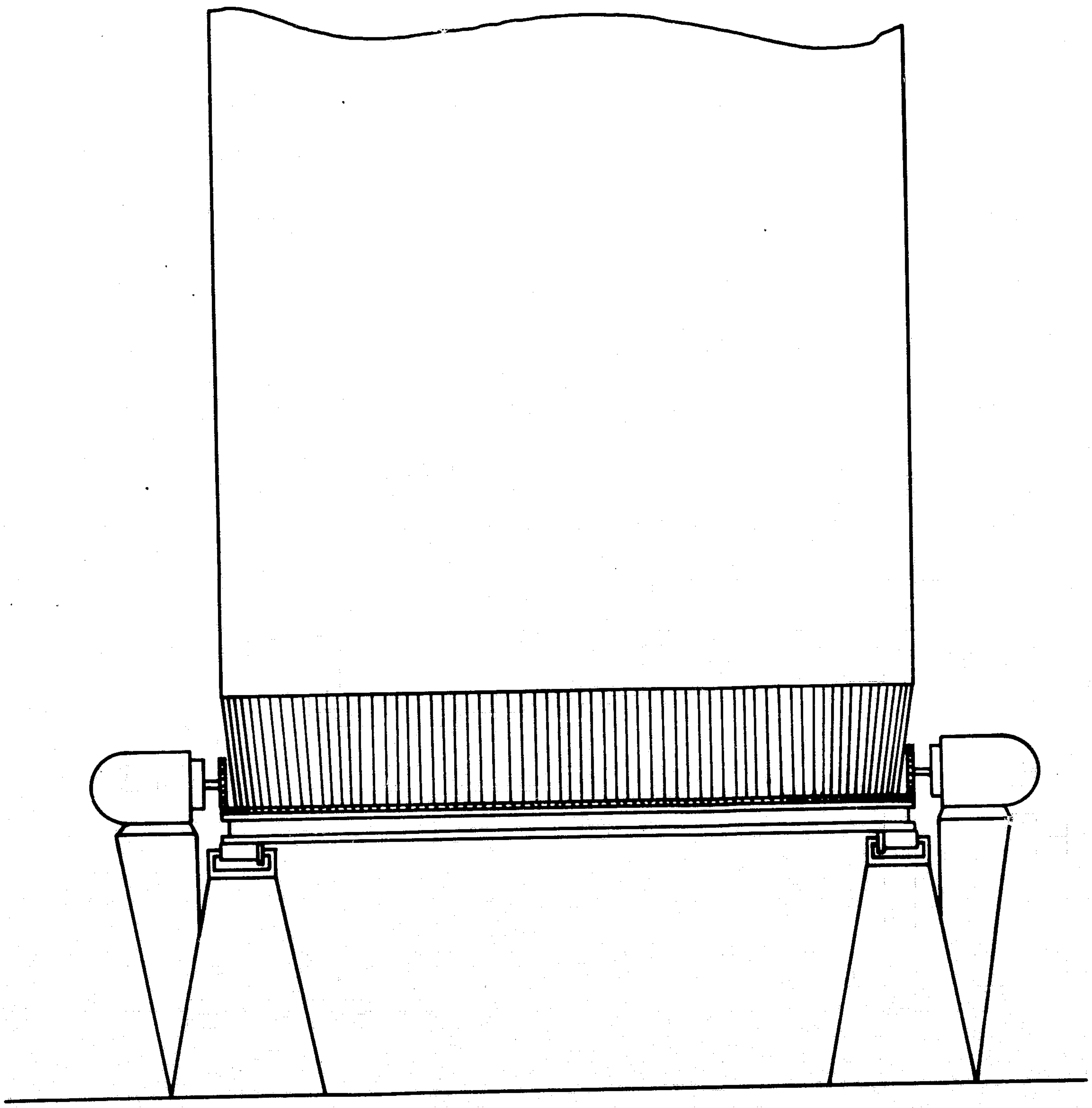


FIGURE 5.2.6.2-2 TANK ROTATION (VERTICAL ASSEMBLY STATION)

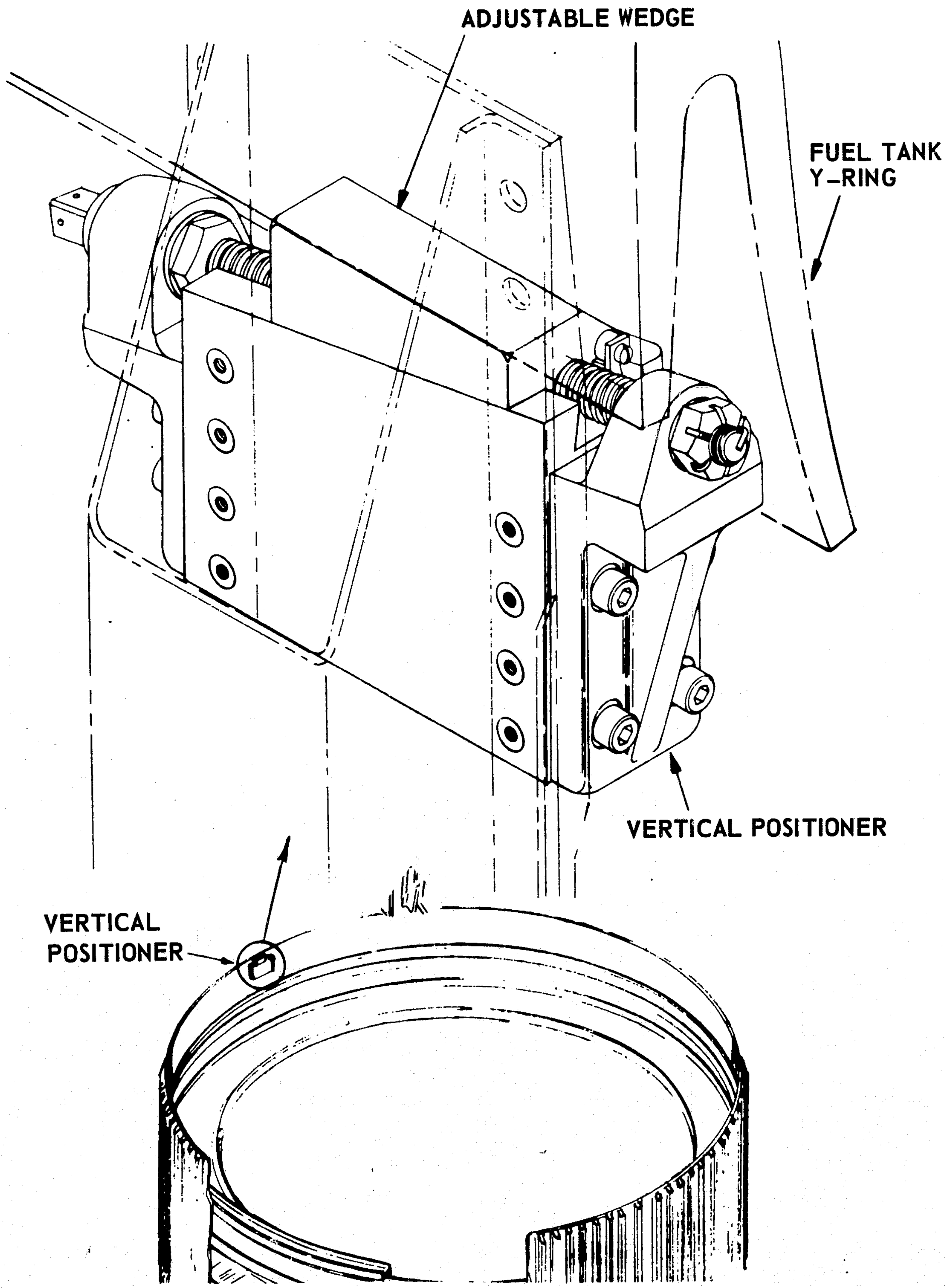


FIGURE 5.2.6.2-3 AFT SKIRT VERTICAL POSITIONER

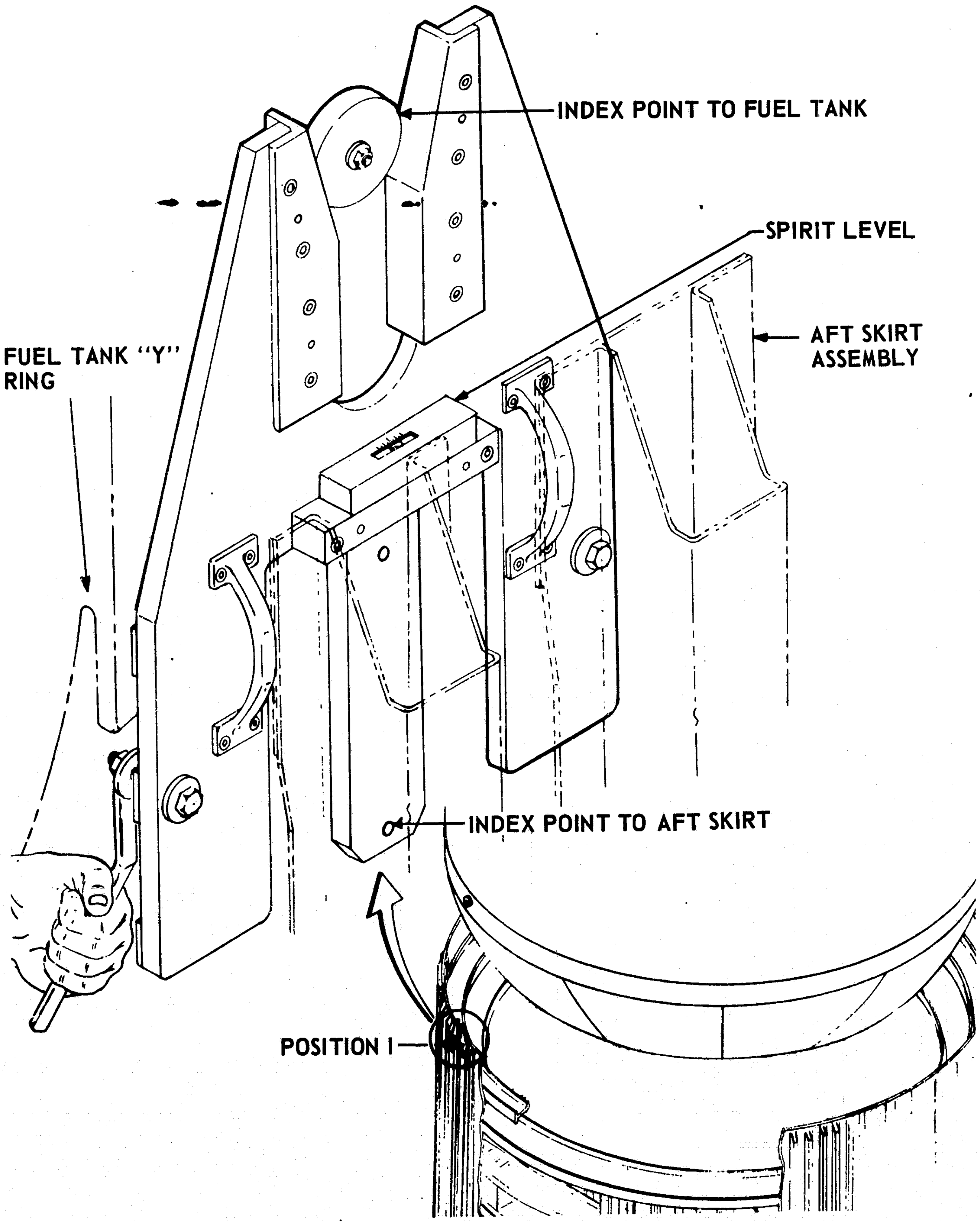


FIGURE 5.2.6.2-4 AFT SKIRT ROTATIONAL POSITIONER

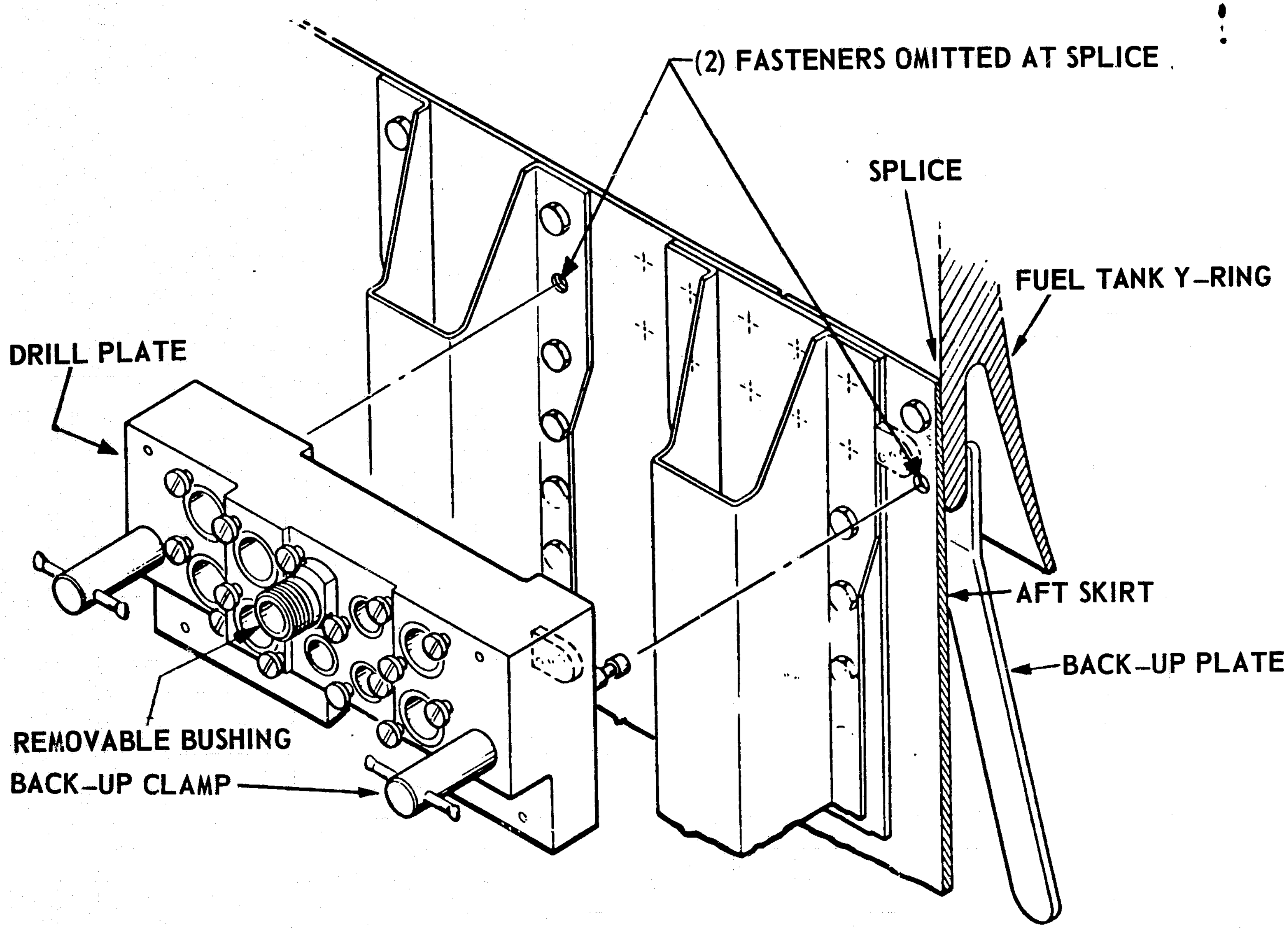


FIGURE 5.2.6.2-5 AFT SKIRT DRILL PLATE

5.2.6.3 (Continued)

The acid is immediately followed by a hot air rinse dry operation. The surface is then primed and allowed to air dry. Foam is applied with a bank of vertical nozzles at a single location while the tank rotates. A diamond sintered cylinder for grinding replaces the brush used in the acid-clean operation. The rotating cylinder is moved vertically while the tank rotates about the track station. The surface is thus sanded smooth and then coated with polyurethane resin using the nozzle bank and tank rotation technique. (Figure 5.2.6.3-1.)

The lower bulkhead is treated and coated in a similar manner. This is accomplished using an elliptical track for radial movement of cleaning and foaming devices.

All wiring common to the forward and aft skirts is now installed in the external tunnels. Tunnels covered are reinstalled prior to final painting.

5.2.6.4 Painting

The polyethylene sheets covering the forward and aft skirts are removed. The tanks are then masked and painted, using the nozzle bank and tank rotation method. The complete foam preparation, application, and painting sequence is shown on Figure 5.2.6.3-1.

5.2.6.5 Transportation

With the forward handling ring still attached to the forward skirt, two trunnion fittings are mounted on the aft skirt circumferential handling ring. The entire tank assembly is hoisted from the vertical assembly station and positioned above the rear dolly section of the transporter. Two vertically extended hydraulic jacks, mounted on each centerline of the out-board trucks, will receive the trunnions and provide clearance for circumferential ring support rollers as the tank is lowered into the horizontal position. Once the tank is horizontal, the jacks are lowered and the ring engages the support rollers with a gear drive similar to that used for rotating the tank while in the vertical assembly fixture. The trunnions are removed as well as the forward handling ring adapter plates. The tank can now rotate when the gearmotors are energized, Figures 5.2.6.5-1 and 5.2.6.5-2.

5.2.6.6 Aft Trusswork Assembly

After the tank has been locked in place on the transporter, the 48 struts comprising the aft trusswork assembly are mounted and prealigned in two circumferential rings. These rings are hoisted using a three-point handling tool and positioned into the fittings at the base of the aft skirt assembly. A selected number of pins are installed to maintain rigidity. The overhead crane and handling tool are moved away. The tank assembly is rotated past work stations on either side of the transporter where the remainder of the truss fitting pins are installed.

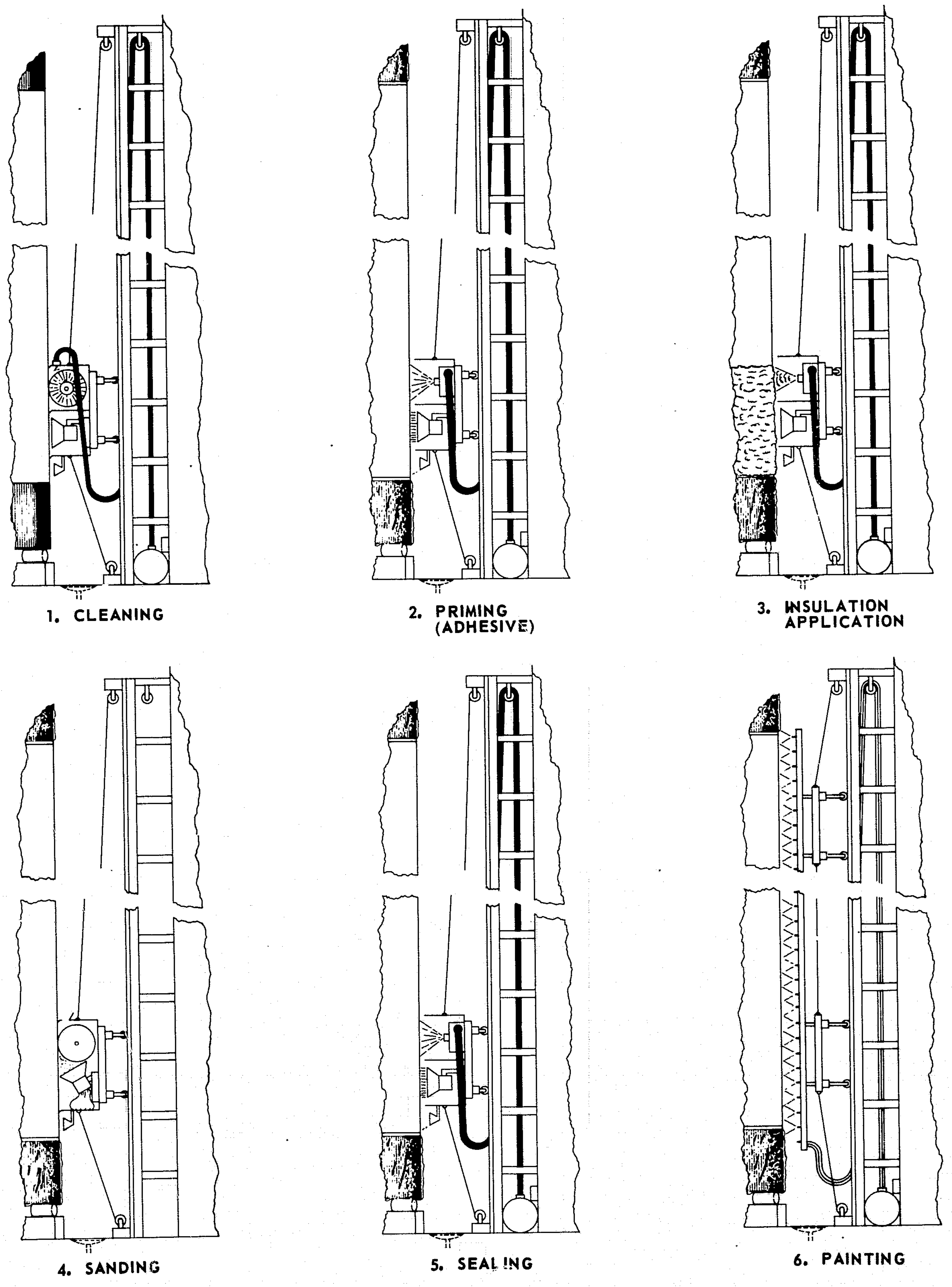


FIGURE 5.2.6.3-1 INSULATION APPLICATION AND PAINTING SEQUENCE

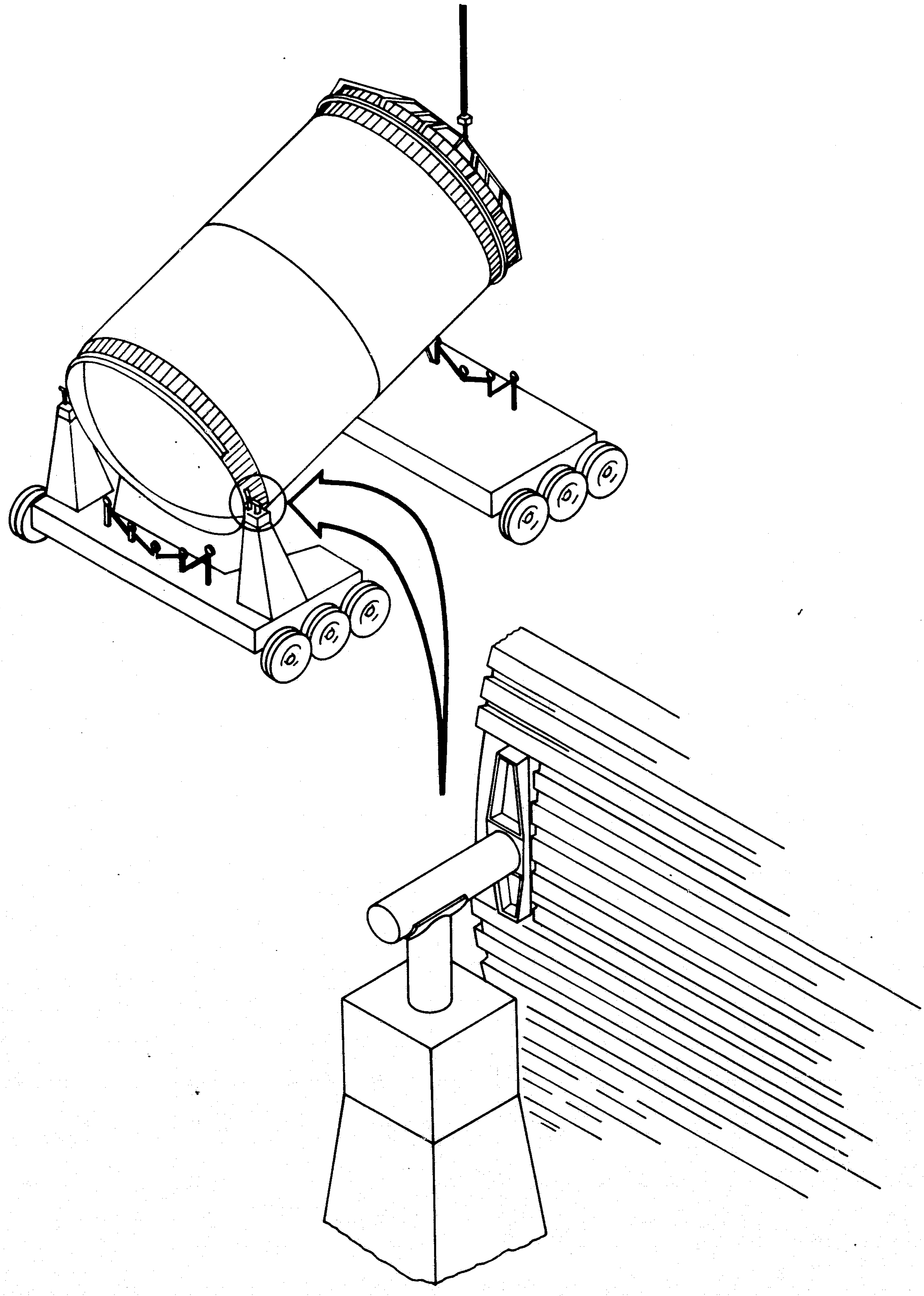


FIGURE 5.2.6.5-1   LOWERING STAGE TO TRANSPORTER

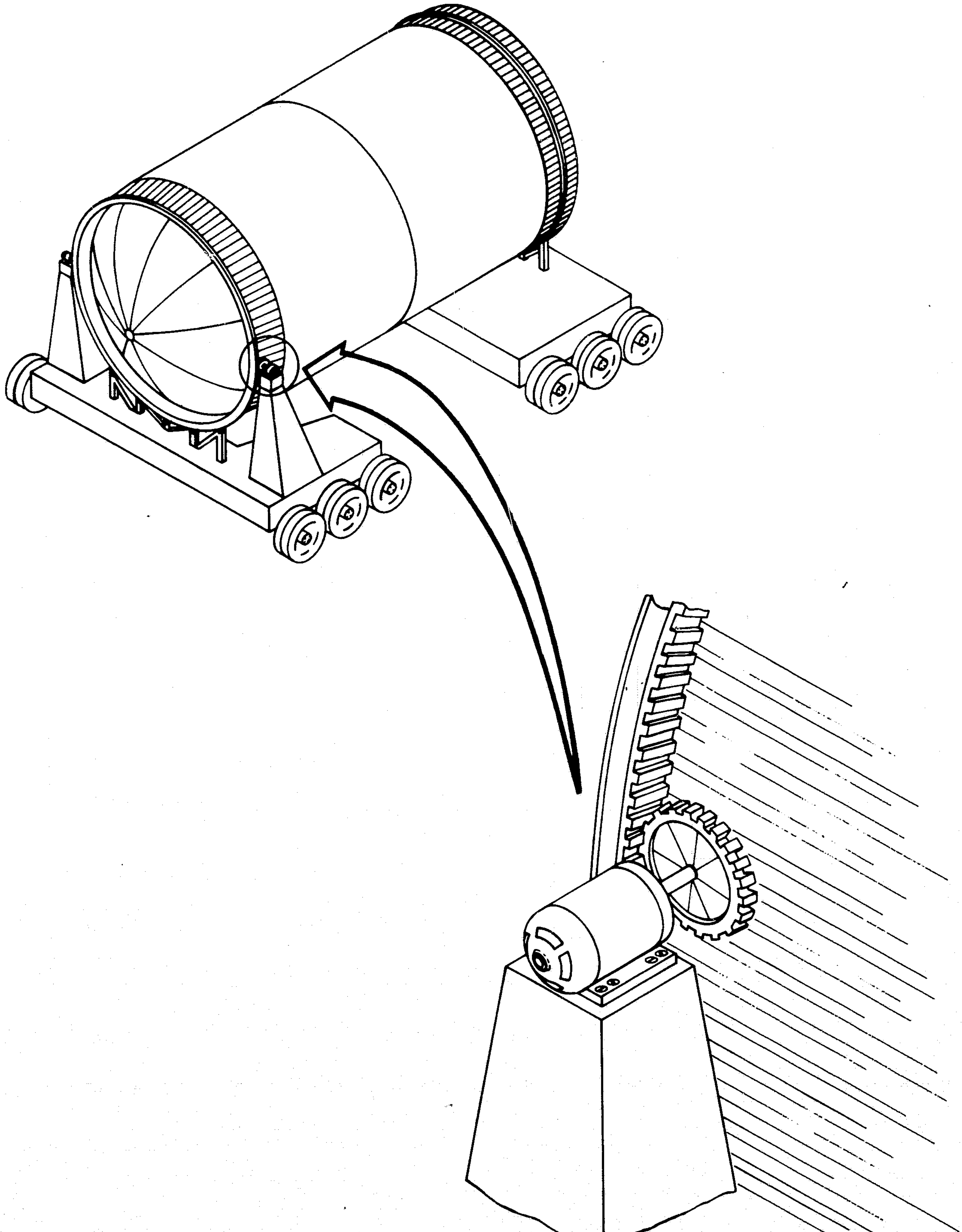


FIGURE 5.2.6.5-2 STAGE ROTATION METHOD FOR ENGINE INSTALLATION

5.2.6.7 Centerbody Plug

With the circumferential rings still in position around the tubular trusswork, a handling ring is used to lift the centerbody plug into position. Attach pins are installed and the plug is now supported in the horizontal position by the tubular trusswork. All remaining piping connecting the centerbody gas generator and manifolds to engine stations is installed.

The trusswork circumferential rings are removed and all preparations are now made to receive the engines and associated equipment, Figure 5.2.6.5-2.

5.2.6.8 Engine Installation

When the centerbody cone is firmly attached, the engines are installed two at a time, positioning them horizontally in their respective mounts. The propellant tank is rotated until the engine mounts on the aft skirt thrust posts align with the engine transporter, then two engines are installed. This process is continued until all 24 engines are installed, Figure 5.2.6.5-2. Dummy engine actuators are installed to hold the engines inboard during tank rotation. All instrumentation wiring, piping, and inspection operations are completed. Tanks are purged with dry nitrogen and sealed. The core stage is now ready for shipment to the launch site for static firing. The inspection operations above include the post manufacturing test and checkout of the completed stage.

5.2.7 Systems Fabrication

The systems covered include the mechanical/propulsion system and the electrical/ electronic system. Each of these major systems is divided into its subsystems. These subsystems are described and the equipment list for their fabrication is identified.

5.2.7.1 Mechanical/Propulsion Systems Fabrication

Propellant Feed Systems — The LOX delivery system consists of 24 ducts approximately 60 feet long, fill and drain ducts, valves and associated tubing and brackets. The ducts will be LOX cleaned and installed during the LH_2 tank build up. The fill and drain ducts will be delivered to the final assembly area, LOX cleaned and ready for installation. Brackets will be fabricated in-house. The butting will be mocked up on the first vehicle using soft tubing. The hard tubing will be fabricated from these. Subsequent tubing will be built using the same mockup tubes, providing the configuration on the second vehicle does not change. Valves will be purchased and delivered to the installation site, LOX cleaned and tested functionally.

The LH_2 delivery system consists of ducts, valve brackets and associated tubing. The same manufacturing approach will be used as in the LOX delivery case. This subsystem will be installed during buildup of thrust bulkhead, and is comprised of the following parts:

5.2.7.1 (Continued)

a. Ducts - AMLLV 15" Dia. x 75' (24 ea) + 15" Dia. 35' (24 ea)
MLLV 11" Dia. x 60' (24 ea) + 11" Dia. 281 (24 ea);

b. Valves - AMLLV (24 ea) 15" Dia.
MLLV (24 ea) 11" Dia.;

c. Brackets, miscellaneous;

d. Tubing - AMLLV (200')
MLLV (160').

Pressurization System — The pressurization of the LOX tank will consist of approximately 160 feet of ducts, 950 feet of tubing, a large manifold 8 inches in diameter by 32 inches long [10 inches in diameter by 40 inches long], pressure switch - one each, relief switch - one each, vent and relief valves - four each, pressure regulator - one each, manifold valve - one each, and associated bracketry.

The above hardware will be fabricated, LOX cleaned and then installed at the final assembly position. The tubing will be fabricated from mockup tubes that will be made on the first vehicle.

The pressurization system for the LH_2 tank consists basically of the same components as the LOX tank pressurization subsystem. Ducts and tubing lengths will be shorter. The parts that comprise this subsystem are as follows:

a. Ducts - AMLLV (8" Dia. 200')
MLLV (6" Dia. 160');

b. Valves - AMLLV (20" Dia.)
MLLV (15" Dia.);

c. Brackets (100 ea.);

d. Tubing - AMLLV (1500')
MLLV (1190');

e. Switches (4 ea.);

f. Manifolds (1 ea.);

g. He Bottles - AMLLV (10 ea., 20" Dia. x 22')
MLLV (10 ea. 16" Dia. x 17');

h. Solenoid Valves.

5.2.7.1 (Continued)

Engine Control — The basic components will be tubing, valves, actuators, and associated bracketry as follows:

a. Ducts - AMLLV 2" Dia. x 30' (24 ea.)
MLLV (1 3/4" Dia. x 24" (24 ea.);

b. Tubing - AMLLV (120')
MLLV (95');

c. Solenoid Valves (24 ea.).

Destruct Ordnance — This subsystem will consist of a shaped charge, cowling, and associated brackets. The installation will be accomplished by mechanical fastening. This subsystem is comprised of the following:

a. Cowling - AMLLV (200')
MLLV (160');

b. Charge.

Environmental Control — This subsystem basically consists of teflon ducts, manifold and associated brackets. The ducts will be purchased and delivered to the installation store. The manifolds and associated hardware will be fabricated and delivered to the store for installation. This subsystem is comprised of the following:

a. Manifolds;

b. Ducting - AMLLV (600')
MLLV (475');

c. Bracketry;

d. Orifices.

Ordnance — The retrorockets will be solid-fuel motors with associated bracketry, which includes:

a. Retro Rockets assembly;
b. Motors;
c. Brackets.

Control Pressure — The control pressure system supplies N_2 gas to various functional valves for actuation purposes. This system consists of tubing, check valves, solenoid valves, orifices and bracketry, which includes:

5.2.7.1 (Continued)

a. Tubes - AMLLV (1200')
MLLV (950');

b. Valves.

5.2.7.2 Electrical/Electronics Fabrication

Electrical/electronic system is comprised of the following subsystems:

a. Electrical Power and Network;

1. Power subsystem,
2. Distributor and Network;

b. Data;

1. Measurement,
2. Emergency Detection,
3. On-Board Test and Checkout;

c. Communications and Tracking System;

d. Command Destruct System;

e. Guidance and Control System.

Make/buy packages for the Electrical/Electronic System are listed in Table 5.2.7.2-I.

TABLE 5.2.7.2-I IDENTIFIABLE PRODUCTION PACKAGES, PARTS LIST, MAKE/BUY

Storable Items	System Reference
Package No. 1	Communication System Command Subsystem
Duplexer	
Power Divider	
Ordnance Firing Unit	
Command Receiver	
Command Decoder	
Container	
Top	
Bottom	
Cable Assy. (5)	
Coax Cable	
Coax Connectors (10)	

TABLE 5.2.7.2-I (Continued)

Storable Items	System Reference
Package No. 2	
Antenna	Command Subsystem
Bracket (Plate)	
Package No. 3	
Antenna	Command Subsystem
Bracket (Plate)	
Package No. 4	Data Systems Measurement Subsystem
Transducers (60)	
Signal Conditioners (60)	
Cable Assemblies (60)	
Wire	
Connectors (120)	
Package No. 5	G&C Systems Guidance & Control Subsystem
Steering Control Subsystem	Purchased as a Unit
Stability Control	
Sensor Package	
Thrust Vector Control	
Interface	
Container	
Top	
Package No. 6	Data Systems On-Board Test and Checkout System
Selector Switch	
Case	
Top	
Wire Bundle	
Wire	
Connectors (14)	
Printed Circuit Cards (4)	
Card (Phenolic)	
Resistor (10 ea.)	
Capacitor (5 ea.)	
Transistor (5 ea.)	
Diode (20 ea.)	
Connectors	

TABLE 5.2.7.2-I (Continued)

Storable Items	System Reference
Package No. 7	Electrical and Power Network System Power Subsystem
Battery (10)	
Measurement Power Supply	
Container	
Top	
Package No. 8	Distributor-Network Subsystem
Main Power Distributor	
Case	
Cover	
Wire Bundle	
Connectors (14)	
Wire	
Lacing Bars	
Relay Bracket Assy.	
Bracket	
Relays (20)	
Printed Circuit Card (4)	
Card (Phenolic)	
Connector	
Resistor (10 ea.)	
Capacitor (5 ea.)	
Diodes (5 ea.)	
Switch Selector	
Bus Bars (5)	
Cable Assy. (10)	
Wire	
Connectors (20) Total	

5.2.8 Main Stage Resource Implications

A comprehensive knowledge of resource requirements is needed to support the manufacturing plan as presented. Main stage resource implications have been developed and are correlated and collated below. This information is provided in the following sections.

Manpower - Manpower requirements are identified for fabrication by major assembly and subassembly. This information is reduced to dollars and is presented with supporting data. (Paragraphs 5.2.8.1 and 5.2.8.2.)

Material - Material cost estimates for the MLLV and AMLLV are based on the known dollars per pound of Saturn S-IC structures, applied to estimated weight of similar structures of the MLLV and AMLLV. Recurring costs are calculated for main stage structures and systems materials including propulsion and mechanical, environmental control, LOX and fuel delivery, pressurization systems, etc. (As shown in Paragraph 5.2.8.3.)

Tooling - Tooling lists are by major subassembly of the main stage, i.e., base plug, aft skirt, etc. The major tooling items have been sized and weights determined. (As shown in Paragraph 5.2.8.4.)

Capital Equipment - Requirements are grouped by main stage/major assembly category, i.e., forward skirt, propellant tank, centerbody plug, and includes test equipment, etc. Capital items, general purpose equipment are identified by function. A brief description of the function of each identified capital item is supplied. Equipment costs, non-recurring and recurring, are presented by major category and also by manufacturing areas. (As shown in Paragraph 5.2.8.5.)

Facilities - Facilities requirements are categorized by manufacturing and test requirements, and priced according to get-ready-costs and recurring maintenance costs. Ground rules are developed, and facility needs further classified by physical requirements in the fabrication area, etc. (Paragraph 5.2.8.6.)

5.2.8.1 Main Stage Fabrication, Recurring, Manpower Estimates

The estimates are based on Saturn S-IC experience, because the vehicles costed are similar in materials and type of construction. The estimates were prepared for the 10th unit and factored back up the learning curve to obtain the 1st unit value.

Table 5.2.8.1-I summarizes the direct manufacturing manhour estimates for the study vehicles. These manhours are for the first unit which has been defined as the first flight test vehicle.

Detail backup for the MLLV and AMLLV Direct Manufacturing Manhour Estimates - This document section presents the detail manhour estimates and the rationale used in developing the estimates. The 10th S-IC stage of the Saturn program was used as the base, factors were developed that accounted for size variations and small differences in structural concepts between similar elements, and direct manufacturing manhours for the 10th unit were computed. These manhours were then backed up an 83 percent learning curve (S-IC historical percentage for direct manufacturing labor) to obtain manhours for the first MLLV and AMLLV structural component.

TABLE 5.2.8.1-I SUMMARY OF DIRECT RECURRING MAIN STAGE MANUFACTURING MANHOUR ESTIMATES - AMLLV AND MLLV

ITEM			MANHOURS AMLLV	MANHOURS MLLV
STRUCTURES	MANHOURS AMLLV	MANHOURS MLLV	857,818	550,375
Skirt (Std. Fwd. Skirt)	126,779	79,511		
LOX Tank	213,903	134,759		
LH_2 Tank	259,070	164,135		
Thrust Structure	154,320	97,222		
Base Plug	45,070	28,394		
Tunnels	58,676	46,354		
PROPULSION/MECHANICAL			554,350	554,350
ELECTRICAL/ELECTRONICS			540,467	540,467
INSTRUMENTATION			219,787	219,787
FLIGHT CONTROL			62,410	62,410
STAGE ASSEMBLY			41,783	33,009
ENGINE INSTALLATION			32,467	32,467
MAIN STAGE TOTAL MANHOURS (WITH STD FWD SKIRT)			2,309,082	1,992,865
ALTERNATE FORWARD SKIRT *			291,062	183,369
MAIN STAGE TOTAL MANHOURS (WITH ALT FWD SKIRT)			2,473,365	2,096,363

*STD. FWD. SKIRT MANHOURS REPLACED BY ALTERNATE FORWARD SKIRT

5.2.8.1 (Continued)

Main Stage Forward Skirt, AMLLV — The skirt discussed here is the standard structure that is used when the core stage is flown as a single stage-to-orbit. The AMLLV and S-IC forward skirts are similar in construction, therefore, total cost of forward skirt can be used minus ring assembly.

The following structures are added to the AMLLV forward skirts:

a. Holddown fittings;
b. Two ring assemblies:
   1. One similar to interface ring S-IC forward skirt,
   2. One similar to thrust ring of thrust structure.

Manhours for AMLLV Forward Skirt derived as follows:

a. Outer shell forward skirt minus rings, holddown posts and final assembly:

   1. S-IC M/Hrs. = 4345,

   2. Formula $\frac{\text{(DIA. AMLLV) (Height AMLLV) (Skin Thick)}}{\text{(DIA. S-IC) (Height S-IC) (Skin Thick)}} =$

      $\frac{(72')\ (22')\ (.10)}{(33')\ (10')\ (.10)} = 4.78$

   3. Manhour AMLLV 4345 X 4.78 = 20,769.

b. Rings:

   1. Lower ring similar to interface ring:

      a) Manhours S-IC = 985,

      b) Formula $\frac{\text{(Dia. AMLLV) (Width)}}{\text{(Dia. S-IC) (Width}} =$

         $\frac{(72')\ (25')}{(33')\ (21')} = 2.59,$

      c) Manhours AMLLV 985 X 2.59 = 2551.

   2. Center Ring Assembly similar to Thrust Ring:

5.2.8.1 (Continued)

a) Manhours S-IC = 2667,

b) Formula $\frac{\text{(Dia. AMLLV) (Width AMLLV)}}{\text{(Dia. S-IC) (Width S-IC)}}$ =

$$\frac{(72') \; (57'')}{(33') \; (40'')} = 3.10,$$

c) Manhours AMLLV 2667 x 3. 10 = 8268

c. Holddown Posts - Estimated in detail by considering the amount of material removed from the forging block by numerical machining, number of pockets or hog-outs and the number of holes drilled. Manhours AMLLV = 2,061.

d. Final Assembly:

1) Manhours S-IC = 7243,

2) Formula $\frac{\text{(Dia. AMLLV) (Height AMLLV) (Skin Thickness)}}{\text{(Dia. S-IC) (Height S-IC) (Skin Thickness)}}$

$$\frac{(72') \; (22') \; (.10')}{(33') \; (10') \; (.10')} = 4.78,$$

3) Manhours AMLLV 7243 x 4. 78 = 34,621.

The total of the manhours in the paragraph above is 68,270 and is for the 10th unit. Projecting back to the 1st unit using an 83 percent learning curve gives an estimate of 126,779 manhours.

Main Stage Forward Skirt, MLLV — The manhours for the MLLV main stage forward skirt were based on the manhour estimates for the full size AMLLV main stage forward skirt.

Basis for Factor	Factor		Manhours for AMLLV		Manhours for MLLV
$\frac{\text{Height X Dia. (MLLV)}}{\text{Height X Dia. (AMLLV)}} = \frac{17.4' \text{ X } 57'}{22' \text{ X } 72'} =$	63%	X	126,779	=	79,871

Main Stage Thrust Structure, AMLLV — The major components of this structure were estimated individually. The outer shell (skins and hat stiffner) will be similar to the forward skirt of the S-IC. Thrust ring will be similar to the thrust ring of the S-IC. It will be lighter per area due to use of honeycomb in place of webs. Intermediate rings will be similar to those of S-IC, and the thrust post similar to the holddown post on the S-IC.

Manhour estimates for the AMLLV are shown in Table 5.2.8.1-II.

Table 5.2.8.1-II AMLLV MANHOUR ESTIMATES

- Outer Shell AMLLV vs Outer Shell S-IC - Forward Skirt

  - Formula $\dfrac{\text{(Dia. AMLLV) (Height AMLLV) (Wall Thickness)}}{\text{(Dia. S-IC) (Height S-IC) (Wall Thickness)}}$

    $$\frac{(72')\,(11\ 1/2')\,(.10')}{(33')\,(10')\,(.10')} = 2.51$$

  - S-IC hrs. = 4345

  - AMLLV hrs. = 4345 X 2.51 = 10, 906

- Thrust Ring AMLLV vs Thrust Ring S-IC

  - Formula $\dfrac{\text{(Dia. AMLLV) (Depth)}}{\text{(Dia. S-IC) (Depth)}} = \dfrac{(72')\,(60')}{(33')\,(40')} = 3.27$
  - S-IC hrs. = 2,667

  - AMLLV hrs. = 2667 X 3.27 = 8,721

- Intermediate Rings AMLLV vs Intermediate Ring S-IC

  - Due to lack of information intermediate rings were estimated on weight comparison.

  - Formula $\dfrac{\text{Weight AMLLV}}{\text{Weight S-IC}} = \dfrac{7810}{2985} = 2.62$

  - S-IC M/Hrs.= 6067

  - AMLLV= 6067 X 2.62 = 15,896

- Thrust Post vs S-IC Holddown Post:

  - Formula $\dfrac{\text{(Weight AMLLV)}}{\text{(Weight S-IC)}} = \dfrac{195}{525} = .37$

  - Weight vs weight formula used since these posts will basically be forged and machine finished; therefore, weight should be in direct relation.

  - S-IC Manhours per post-701 (average)

  - AMLLV Manhours 701 X .37 = 259/per post
    259 X 24 = 6216

Table 5.2.8.1-II (Continued)

- Inner Splice Plate

  - Circumference = 226' and there are 12 Hi-LOX/Foot

  - Drill holes through the Skin Aft Skirt and through the plate; therefore, each hole is over 1/2" deep.

    2712 Hole (3 bolts every 3 inches)
    17 Min/Hole
    768 Manhours to drill all holes

  - Install Hi-LOX

    2712 Hi-LOX
    4 Min/Hole
    181 Manhours

  - Total = 181 + 768 = 949 Manhours.

- Final Assembly

  Considering complexity of assembling the thrust ring, thrust post and intermediate rings, the thrust structure final assembly will be based on Final Assembly of the S-IC Thrust Structure. (This excludes center engine support).

  Manhour S-IC = 32,330

  Formula $\frac{\text{(Dia. AMLLV) (Height)}}{\text{(Dia. S-IC) (Height)}} = \frac{(72')(11.5')}{(33')(20')} = 1.25$

  Manhours AMLLV = 32,330 X 1.25 = 40,413

The manhours estimated for the main stage thrust structure of the AMLLV for the 10th unit is 83,101. Projected on the 83 percent learning curve gives 154,320 for the 1st unit manhour estimate.

Main Stage Thrust Structure, MLLV — The manhours for the main stage thrust structure for the MLLV were based upon those for the AMLLV thrust structure.

Basis for Factor	Factor		Manhours for AMLLV	MLLV
$\frac{\text{Height X } \pi\text{Dia.}}{\text{Height X } \pi\text{Dia.}} = \frac{9.1' \text{ X } 57'}{11.5' \text{ X } 72'} =$	.63	X	154,320	= 97,222

5.2.8.1 (Continued)

LH$_2$ Tank, AMLLV - Manufacturing manhours for the vertical welding of the AMLLV LH$_2$ tank have been estimated according to the formula below.

Vertical weld of segments were compared to hours extracted from S-IC actuals. Manhours per vertical foot of weld were figured as follows: Total hours to weld #1, #2, #3 and #4 ring segments were 2583 manhours, which equals 646 manhours per cylinder. There are four ten-foot welds per cylinder.

$646 \div 4 = 162$ manhours per 10-foot weld

$162 \div 10 = 16.2$ manhours per foot weld

Total feet of weld for AMLLV = 50' X 20 segments = 1000 per 50' cylinder
1000 X 2 (cylinders) = 2000' weld

AMLLV manhours = 16.2 X 2000 = 32,400 manhours

Installation of ring baffles is similar to that of the S-IC.

Manhours S-IC = 5,286

Formula $\dfrac{(\text{Dia. AMLLV})\ (\text{No. Rings})}{(\text{Dia. S-IC})\ (\text{No. Rings})} =$

$$\frac{(72')\ (20)}{(33')\ (13)} = \frac{1440}{429} = 3.36$$

AMLLV Manhours = 5286 X 3.36 = 17,760 manhours.

Installation of T-stiffeners manhours were figured according to the formula below.

There will be 10 T-stiffeners per skin segment totaling 200 per cylinder. These T-stiffeners will be made from extrusions and bolted onto extensions milled on the skins. Bolts will be approximately 12 inches apart.

50' ÷ 12" = 50 bolts/T-stiffener
200 X 50 = 10,000 bolts/cylinder
10,000 X 2 cylinders = 20,000 bolts total.

5.2.8.1 (Continued)

Estimates are as follows:

a. Drill hole at .25 manhours per hole = .25 X 20,000 = 5,000 manhours;

b. Install bolts at .066 X 20,000 = 1,320 manhours;

c. Assemble ring baffle segment — Hours will be based on actual hours taken from Serial No. 130:

1. Formula $\frac{\text{(Dia. AMLLV) (No. Rings)}}{\text{(Dia. S-IC) (No. Rings)}} = \frac{(72')\ (20)}{(33')\ (13)} = \frac{1440}{429} = 3.36,$

2. S-IC actual manhours = 3652,

3. Manhours AMLLV 3652 X 3.36 = 12,271;

d. Fabrication of skin segments — Hours based on actuals recorded in Wichita for S-IC:

1. Formula $\frac{\text{(Dia. AMLLV) (Height) (Thickness)}}{\text{(Dia. S-IC) (Height) (Thickness)}}$

$$\frac{(72')\ (50')\ (1.5'')}{(33')\ (10')\ (2.0'')} = \frac{54000}{660} = 8.2,$$

2. Total S-IC hours for No. 2 Cylinder Assembly = 1027 manhours, hours to fabricate thr four skin segment,

3. AMLLV manhours = 1027 X 8.2 = 8,421 manhours,

4. Two 50-foot cylinders = 8,421 X 2 = 16,842 manhours;

e. Horizontal weld, weld two tank cylinders together — horizontal weld will be compared to the average cylindrical weld time per foot of the S-IC fuel tank and LOX tank horizontal weld:

1. S-IC manhours = 1313,
2. Welding hours/foot = 1313 divided by 104 = 12.63,
3. 12.63 X 226' = 2,855;

f. Horizontal Weld, weld bulkheads to tank cylinders — welding the bulkheads to the cylinder on the S-IC:

1. Formula $\frac{\text{Dia.} \times \pi}{\text{Dia.} \times \pi} = \frac{72' \times 3.14}{33' \times 3.14} = 2.2,$

5.2.8.1 (Continued)

2. Manhours AMLLV 1466
$$\begin{array}{r} 1466 \\ \underline{\times 2.2} \\ 3225 \text{ M/Hrs. per bulkhead} \\ \underline{\times 2} \\ 6450 \text{ M/Hrs. Upper \& Lower Bulkheads;} \end{array}$$

g. Assembly and installation of cruciform baffles will be figured on the same ratio as ring baffles due to no information; 36,071 m/hrs.

h. LOX Tunnel installation — This is based on a ratio of number of engines with the S-IC:

1. Engine ratio $\frac{24}{5} = 4.8,$

2. S-IC Manhours = 1779,

3. AMLLV Manhours = 4.8 X 1779 = 8539 manhours

The LH_2 tank manufacturing manhours when projected back up the learning curve equals 259,070 for the 1st unit.

LH$_2$ Tank, MLLV -- The manhours for the MLLV LH_2 tank were factored from the LH_2 tank structure manhours for the AMLLV.

	Factor	Manhours AMLLV	Manhours MLLV
Bulkhead Factor (Area) $\frac{\pi R^2}{\pi R^2} = \frac{(28.5')^2 \times 3.14}{(36')^2 \times 3.14} =$	.6335 x	259, 070 =	164,135

Cylindrical Factor $\frac{79 \times 57}{100 \times 72} = .6335$

the .6335 factor is applied to the total tank.

LOX Tank, AMLLV — The LOX tank consists of the common bulkhead and the upper bulkhead with a center ring. Manhours for AMLLV are derived as follows:

a. Bulkheads will be compared to those of the S-IC by means of Lateral Surface Area:

1. Formula $\dfrac{\frac{4 \; R^2}{2} \text{(AMLLV)}}{\frac{4 \; R^2}{2} \text{(S-IC)}}$

$$\frac{\frac{(4)\,(3.14)\,(36^2)}{2}}{\frac{(4)\,(3.14)\,(17.54)}{2}} = 4.79$$

5.2.8.1 (Continued)

This is the formula for figuring a half sphere, but all things considered equal this should give an accurate ratio. A second formula was used based as follows and verifies the above,

$$\frac{\text{(Horizontal Weld AMLLV) (Vert. Weld)'' (Qty. of Welds)}}{\text{(Horizontal Weld S-IC)'' (Vert. Weld)'' (Qty. of Welds)}} =$$

$$\frac{(339'')\ (348'')\ (20)}{(289'')\ (213'')\ (8)} = \frac{2,359,440}{492,456} = 4.79$$

Weight of 3 S-IC bulkheads = 20,378 lbs.

20,378 x 4.79 Surface Area Ratio AMLLV = 97,611 lbs. for S-IC - for same surface area.

$$\frac{\text{125,425 lbs. weight AMLLV}}{\text{97,611 lbs. - S-IC weight.}} = \text{1.28 factor for thickness projected from factor}$$

2. Manhours S-IC - 6,076,

3. AMLLV Manhours 6,076 x 4.79 = 28,983
28,983 x 1.28 = 37,098;

b. Manhours for the common bulkhead assembly based on hours to build two bulkheads, plus honeycomb installation manhours detail estimated,

AMLLV Manhours

2 upper bulkheads = 2 x 37098 =	74196
Honeycomb installation	916
	75112 ;

c. Manhours for the fabrication and assembly of the center ring based on same formula as the lower ring AMLLV aft skirt;

1. $$\frac{\text{(Dia. AMLLV) (Width AMLLV)}}{\text{(Dia. S-IC) (Width S-IC)}} = \frac{(72'')\ (25'')}{(33'')\ (21'')} = 2.59,$$

2. Manhours S-IC = 985,

3. Manhours AMLLV = 985 x 2.59 = 2551;

d. Manhours for mating the common bulkhead with the upper bulkheads were detail estimated,

425 manhours - Detail estimated.

5.2.8.1 (Continued)

The sum of the above LOX tank manufacturing manhours is 115,186 for the tenth unit. Unit No. 1 projected back up the 83 percent learning curve is estimated at 213,903 manhours.

LOX Tank, MLLV — The manhours for the LOX tank were factored from the LOX tank structure manhours for the AMLLV.

Basis for Factor	Factor	Manhours for AMLLV	Manhours for MLLV
Same as LH_2 Tank	.63	213, 903	134,759

Base Plug, AMLLV — No structure on the S-IC stage is comparable to the plug on the core stage; therefore, detail estimation of the manhours was required. The AMLLV manhour estimates are as follows:

a. There are approximately 25,166 inches of weld in the plug. Based on a rate of .96 manhours per inch, S-IC actuals, 24,107 manhours are required for this operation;

b. Fabrication of truss plates was estimated at 12 manhours;

c. Fabrication of bulkhead segments, based on S-IC actuals for tank bulkheads, was estimated at 87 manhours;

d. Assembly of inner and outer faces and trim was estimated at 32 manhours;

e. Bonding of the backup structure was estimated at 32 manhours.

The tenth unit estimate for the base plug fabrication totaled 24,270 manhours. First unit manhours was projected back up the learning curve to 45,070 manhours.

Base Plug, MLLV — The manhours for the base plug for the MLLV were factored from the AMLLV base plug manhours.

Basis for Factor	Factor
$\frac{\text{Dia. x Height}}{\text{Dia. x Height}} = \frac{43.5' \times 17.4'}{55' \times 22'} =$	.63

Bulkhead Factor

$$\frac{\pi R^2}{\pi R^2} \quad \frac{(13)^2 \times 3.14}{(16.5)^2 \times 3.14} = .63$$

Factor	Manhours for AMLLV	Manhours for MLLV
.63	45,070	28,394

5.2.8.1 (Continued)

Tunnels, AMLLV — Manhours for fabrication of the tunnels is based on a ratio of the stage sizes. Consideration was given to an engine ratio number, but it was felt that the problem of manufacturing the AMLLV tunnels is not in direct ratio to the larger S-IC tunnels. The AMLLV manhour estimates are as follows:

a. $\frac{\text{(Dia. AMLLV) (Height)}}{\text{(Dia. S-IC) (Height)}} = \frac{(72')\ (158')}{(33')\ (138')} = 2.5;$

b. Manhours S-IC = 12,639;

c. Manhours AMLLV = (12,639) (2.5) = 31,597.

First unit estimate for manufacture of the AMLLV tunnels = 58,676

Tunnels, MLLV — The manhours for the tunnels for the MLLV were factored from the AMLLV tunnels manhours.

Basis for Factor	Factor	Manhours for AMLLV	Manhours for MLLV
Decrease only with height	.79	58,676	46,354

Final Structural Assembly, AMLLV — Manhours for the stacking of the subassemblies in the vertical position will be based on a size comparison to those of the S-IC. Manhours for the final assembly of structures on the S-IC are as follows:

a. 9000 manhours per stage.

b. Formula $\frac{\text{(Dia. AMLLV) (Height AMLLV)}}{\text{(Dia. S-IC) (Height S-IC)}} = \frac{(72')\ (158')}{(33')\ (138')} = 2.5;$

c. Manhours AMLLV 9,000 x 2.5 = 22,500.

Tenth unit estimate for final structural assembly of the AMLLV main stage, projected to first unit on the 83 percent learning curve, is 41,783 manhours.

Final Structural Assembly, MLLV — The final assembly manhours for the MLLV was factored from the AMLLV.

Basis for Factor	Factor	Manhours for AMLLV	Manhours for MLLV
Decrease only with Diameter	.79	41,783	33,009

System Installation, AMLLV — AMLLV systems will be very comparible to those of the S-IC.

System requirements common to both are:

5.2.8.1 (Continued)

		Manhours /S-IC
a.	Propellant Feed Systems	56,785
b.	Electrical	55,363
c.	Instrumentation	22,514
d.	Flight Control	6,393
		141,055

The quantity of engines will directly affect the above systems; therefore, an engine's ratio, S-IC compared to AMLLV, was derived and applied to S-IC manhours.

Formula $\frac{\text{Qty. Engines AMLLV}}{\text{Qty. Engines S-IC}} = \frac{24}{5} = 4.80.$

$4.80 \times 141{,}055 = 677{,}063$

Plus: 9.50% added to allow for the capability of the engines

$677{,}063 \times 9.5 = 64{,}321 + 677{,}063 = 741{,}384$

The estimated system installation manhours for the tenth unit is 741,384 manhours, projected to the first unit gives an estimate of 1,377,014 manhours.

Systems Installation, MLLV — The systems are comparable between the AMLLV and the MLLV. The manhours used, therefore, were the same; 1,377,014.

Engine Installation, AMLLV — It is believed this operation is very similar to that required to mount the engines on the S-IC stage. Although the engines are smaller, they will have about the same number of attachments and interfaces:

a. S-IC manhours = 6,764;

b. Formula $\frac{\text{AMLLV Engines}}{\text{S-IC Engines}} = \frac{24}{5} = 4.8;$

c. AMLLV manhours $6{,}764 \times 4.8 = 32{,}467$.

Engine Installation, MLLV — The engine installation manhours are the same for both the AMLLV and MLLV as they both use 24 engines.

Alternate Forward Skirt, AMLLV — The skirt discussed here is the heavy structure that has provisions for reacting the thrust loads of the strap-on SRM stages and the increased injection stage and payload weights. Rationale for manhour estimates are the same as those presented for the standard skirt. AMLLV manhours derived as follows:

a. Outer shell less rings, SRM attachment fittings and final assembly:

1. S-IC manhours = 4,345,

5.2.8.1 (Continued)

2. Formula

$$\frac{\text{(Dia. AMLLV) (Hgt. AMLLV) (Skin Thick)}}{\text{(Dia. S-IC) (Hgt. S-IC) (Skin Thick)}} = \frac{(72')\ (22')\ (.25'')}{(33')\ (10')\ (.10'')} = 12;$$

3. AMLLV manhours 4.345 (12) = 52,140;

b. Lower ring;

1. S-IC manhours = 985,

2. Formula $\frac{\text{(Dia. AMLLV) (Width)}}{\text{(Dia. S-IC) (Width)}} = \frac{(72')\ (25'')}{(33')\ (21'')} = 2.59,$

3. AMLLV manhours = 985 x 2.59 = 2,551;

c. Center ring;

1. S-IC manhours = 2,667,

2. Formula $\frac{\text{(Dia. AMLLV) (Width AMLLV)}}{\text{(Dia. S-IC) (Width S-IC)}} = \frac{(72')\ (90'')}{(33')\ (40'')} = 4.9;$

3. AMLLV manhours = 2,667 x 4.9 = 13,068;

d. Posts — Same as the posts for the standard skirt, 2,061 manhours;

e. Final Assembly:

1. S-IC manhours 7,243,

2. Formula $\frac{\text{(Dia. AMLLV) (Height) (Skin Thick)}}{\text{(Dia. S-IC) (Height) (Skin Thick)}} = \frac{(72')\ (22')\ (.25'')}{(33')\ (10')\ (.10'')} = 12,$

3. AMLLV manhours = 7,243 x 12 = 86,916.

Total manhours for the alternative (heavy weight) forward skirt tenth unit is 156,736. First unit manhours projected back up the 83 percent learning curve are 291,062.

Alternate Forward Skirt, MLLV — The alternate vehicle used a heavyweight forward skirt for strap-on applications. All other cost items were identical. The MLLV alternate forward skirt manhours were factored from the AMLLV alternate forward skirt.

Basis for Factor	Factor	Manhours for AMLLV	Manhours for MLLV
$\frac{\text{Height} \times \pi \times \text{Dia.}}{\text{Height} \times \pi \times \text{Dia.}}$	$= \frac{17.4' \times 57'}{22' \times 72'} = .63$	291,062	= 183,369

5.2.8.2 Manhours: Main Stage Manufacturing Manhours Estimates, Nonrecurring

Estimates for manufacturing and engineering labor for get ready costs were prepared by the Boeing-Michoud organization. Table 5.2.8.2-I summarizes the direct manhours that were provided to the Finance department for the costing activity. These estimates do not include the manhours associated with facility brick and mortar, capital equipment, construction and installation.

The rationale used in preparing these estimates is based on S-IC experience.

5.2.8.3 Main Stage Materials

Main Stage MGSE Materials, Nonrecurring

Material Cost S-IC	$3,345,269
AMLLV Size Ratio	2.5
AMLLV Material Cost	$8,363,173
MLLV Size Ratio	1.51
MLLV Material Cost	$5,051,368

Main Stage Structural Materials, Recurring — Material dollars based on the known dollars per pound of S-IC structures, applied to the estimated weights of similar structures of the AMLLV and MLLV are listed below:

Structure	Material $ AMLLV	Weight AMLLV	S-IC $/LB.	Material $ MLLV	Weight MLLV
Forward Skirt	262,977	38,730	6.79	198,913	29,294
Thrust Structure	218,765	32,030	6.83	120,242	17,604
LH_2 Tank (Contains Tunnels)	3,160,061	206,675	15.29	1,660,232	108,582
LOX Tank	998,363	125,425	7.96	488,442	61,362
Base Plug	291,447	15,900	18.33	163,595	8,925
Alt. Fwd. Skirt	500,491	73,710	6.79	339,534	50,005

Main Stage Systems Materials, Recurring — Materials for some of the systems were based on comparison of similar system S-IC material costs. The estimating rationale and detail costs are discussed in the following paragraphs. Total systems materials costs are $28,173,495 for the AMLLV and $25,356,146 for the MLLV.

Propulsion and Mechanical Systems — These costs were based on a function of engine numbers.

$$\frac{24}{5} = 4.8$$

AMLLV cost = 4.8 (S-IC cost) = $249,715

MLLV cost is the same as the number of engines are the same.

TABLE 5.2.8.2-I SUMMARY OF NONRECURRING MAIN STAGE DIRECT MANUFACTURING MANHOUR ESTIMATES - AMLLV & MLLV

Cost Item	Full Size AMLLV (Manhours)		Half Size MLLV (Manhours)	
	Standard *	Alternate **	Standard	Alternate
Main Stage				
Engine Installation GSE	54,235	54,235	54,235	54,235
Engine Installation Planning	17,355	17,355	17,355	17,355
GSE Fab and Erect	1,990,190	1,990,190	1,639,404	1,639,404
Tool and Production Plan	5,146,005	5,489,360	3,533,523	3,749,836
Tool Fab and Erect	11,821,160	12,729,860	7,447,331	8,019,812
Tool Design	4,456,577	4,799,157	2,807,644	3,023,469
Manufacturing Development	506,559	540,088	347,821	369,125
Total	23,992,081	25,620,245	15,775,723	16,801,646

* A Standard Vehicle uses the Lightweight Skirt
** An Alternate Vehicle uses the Heavyweight Skirt

5.2.8.3 (Continued)

Environmental Control System — Forward compartment is based on a 50 percent increase for the AMLLV above the S-IC systems cost due to redundant systems added and additional on-board test and checkout system (S-IC cost - $12,981).

Cost = $19,472,

For the MLLV this increase is 25 percent and cost $9,736.

Aft compartment is based on the AMLLV/S-IC volume ratio.

Cost = $63,252.

Aft Compartment cost is based on the MLLV volume ratio.

Cost = $31,626.

LOX Delivery System — LOX Delivery system was developed as a function of line-size and length. The sensor cost was held constant with S-IC values.

	AMLLV	MLLV
System less sensors	$7,500,273	$7,164,233
Sensors	6,621	6,621
	$7,506,894	$7,170,854

Fuel Delivery System — Same as LOX system rationale.

	AMLLV	MLLV
System less sensors	$14,134,058	$13,498,551
Sensors	24,331	24,331
	$14,158,389	$13,622,882

Retro-Rocket System — The AMLLV uses 16 of the S-IC retro-rockets.

Cost = $333,624.

The MLLV uses 10 of the S-IC retro-rockets.

Cost = $208,515.

Fuel Pressurization System — The system cost is based on a volume of LOX tank/burn time ratio with the S-IC with controls, etc., being held constant for the AMLLV.

5.2.8.3 (Continued)

System less controls =	$2,390,519
Controls, etc.	73,834
	$2,464,353

For the MLLV system less controls =	$1,195,259
controls	73,834
	$1,269,093

LOX Pressurization system — Same as fuel system.

	AMLLV	MLLV
System less controls	$390,827	$195,414
Controls, etc.	68,671	68,671
	$459,498	$264,085

Control Pressure System — Same as the S-IC for both AMLLV and MLLV - $35,809.

Main Stage Liquid Engines - All engines will be contractor furnished equipment.

Electrical System — Stage sequencing is the same as the S-IC for both AMLLV and MLLV = $18,910. Emergency malfunction detection is the same as the S-IC for both AMLLV and MLLV = $45,100. Power generation and conversion is twice the S-IC value for both AMLLV and MLLV = $32,674. Destruct, EBW, is 24 percent greater than the S-IC for both AMLLV and MLLV = $38,836. The total of these electrical system costs is $135,520. Cabling and distribution for the S-IC is $127,210. Cabling and distribution for the AMLLV is based on a developed factor

$$\frac{\text{AMLLV Diam. x Length}}{\text{S-IC Diam. x Length}} = 2.49,$$

2.49 x $127,210 = $316,765 (for AMLLV)

Total electrical system for the AMLLV = 135,520 + 316,765 = $452,285

The electrical system for the MLLV is estimated to be 90% of the AMLLV costs due to the shorter cabling and distribution runs.

The electrical system for the MLLV = $452,285 x 90% = $407,057

Instrument System — S-IC has 400 measurements. Allow 600 for the AMLLV or MLLV due to on-board test and checkout. Cost = $455,007. Radio frequency, RF, is then the same as S-IC = $16,625. Telemetry cost = $101,151. Total instrumentation for the system = $572,783. The MLLV is estimated to be 90% of the AMLLV because of shorter cabling and distribution runs, or $515,505.

5.2.8.3 (Continued)

Flight Control Systems — These systems are based on the number-of-engine ratio with the S-IC. Both the AMLLV and MLLV have 24 engines.

Fluid Power	$ 681,259
Thrust Vectoring	$1,107,897
Instruments	$ 68,265
	$1,857,421

The MLLV is estimated at 90% of the AMLLV because of shorter cabling and distribution runs, or $1,671,679.

Mainstage Material Cost Summary — Table 5.2.8.3-I summarizes recurring material costs for manufacture of the AMLLV and MLLV main stage.

TABLE 5.2.8.3-I MAIN STAGE MATERIAL COST SUMMARY - AMLLV AND MLLV

ITEM			AMLLV	MLLV
STRUCTURES			$ 4,931,613	$ 2,631,424
	AMLLV	MLLV		
Skirt	$ 262,977	$ 198,913		
Lox Tank	998,363	488,442		
LH_2 Tank	2,710,109	1,449,920		
Thrust Structure	213,765	120,242		
Base Plug	291,447	163,595		
Tunnels	449,952	210,312		
PROPULSION/MECHANICAL			25,291,006	22,761,905
ELECTRICAL/ELECTRONICS			452,285	407,057
INSTRUMENTATION			572,783	515,505
FLIGHT CONTROL			1,857,421	1,671,679
STAGE ASSEMBLY - W/STD. FWD. SKIRT			$33,105,108	$27,987,570
ALTERNATE FWD SKIRT (STD FWD SKIRT DEDUCTED)			500,491	339,534
MAIN STAGE WITH ALT. FWD SKIRT			$33,342,622	$28,128,191

5.2.8.4 Main Stage Tooling and Capital Equipment

The tooling lists which follow identify the manufacturing tooling and capital equipment necessary to fabricate the main (core) stage. For many of the major tooling items, the tooling concepts are illustrated in Section 5.2.1 through 5.2.5. The major tooling items have been sized and the weights determined. The tooling requirements have been divided into tooling for the forward skirt, propellant tanks, aft skirt, centerbody plug and the final assembly.

Main Stage Tooling Material, Nonrecurring - All material dollars based on $1.75 per tooling production manhour. This is a standard factor utilized for tool material estimates. Table 5.2.8.4-I tabulates these costs, with total dollars including categories not itemized here.

TABLE 5.2.8.4-I MAIN STAGE TOOLING MATERIAL, AMLLV AND MLLV - NONRECURRING

ITEM			AMLLV	MLLV
STRUCTURES				
	AMLLV	MLLV		
Fwd. Skirt	$ 1,762,215	$1,110,195		
LOX Tank	4,038,262	2,544,105		
LH_2 Tank	10,362,534	6,528,396		
Thrust Str.	1,457,365	918,140		
Base Plug	723,450	455,774		
Tunnels	709,800	447,174	$19,053,626	$12,003,784
PROPULSION/MECHANICAL			2,265,127	1,427,030
ELECTRICAL/ELECTRONICS			40,404	25,455
INSTRUMENTATION			55,556	35,000
FLIGHT CONTROL			164,164	103,423
SUBTOTAL			$21,578,877	$13,594,692
GSE			8,363,173	8,363,173
ALT. FWD. SKIRT			(3,353,805)	(2,112,897)
MAIN STAGE WITH STD. FWD. SKIRT			$29,942,050	$21,957,865
MAIN STAGE WITH ALT. FWD. SKIRT			$31,533,640	$22,960,567

Main Stage Tooling Manhour Summary, Nonrecurring — Table 5.2.8.4-II is a summary of tooling fabrication and erection manhour nonrecurring costs.

5.2.8.4 (Continued)

TABLE 5.2.8.4-II TOOLING MANHOUR REQUIREMENTS - NONRECURRING SUMMARY

ITEM			AMLLV	MLLV
STRUCTURES			10,887,786	6,859,301
	AMLLV	MLLV		
Skirt	1,006,980	634,397		
Lox Tank	2,307,578	1,453,774		
LH_2 Tank	5,921,448	3,730,512		
Thrust Structure	832,780	524,651		
Base Plug	413,400	260,442		
Tunnels	405,600	255,528		
PROPULSION/ MECHANICAL			1,294,358	815,446
ELECTRICAL ELECTRONICS			23,088	14,545
INSTRUMENTATION			31,746	20,000
FLIGHT CONTROL			93,808	59,099
SUB TOTAL			12,330,786	7,768,391
GSE FAB & ERECTION			1,990,190	1,639,404
ALTERNATE FWD SKIRT			1,916,460	1,207,370
MAIN STAGE WITH STD FWD SKIRT			14,320,976	9,407,795
MAIN STAGE WITH ALT FWD SKIRT			15,230,456	9,980,768

Forward Skirt Assembly Tooling and Capital Equipment — A brief description of the function of each major tool and capital item identified is provided below. Tools, which are special purpose items designed specifically for the MLLV or AMLLV, are identified by the subassembly with which they are associated. Capital items, general purpose equipment are identified by function. The forward skirt consists of the skin panel subassembly, ring frame subassembly and the interface angle-ring subassembly.

a. Subassembly Tools:

1. Skin Panel Subassembly:

a) Skin Panel Subassembly Fixture - used to build up the complete subassembly from skins, hat section stringers and holddown post, if required; see prior Figure 5.2.1.1-1,

5.2.8.4 (Continued)

b) Personnel Platform - used to provide access to skin panel subassembly fixture, prior Figure 5.2.1.1-1,

c) Hat section filler bonding tool - a clamp to facilitate bonding a stepped filler to the joggled ends of the hat sections, permitting the fastener heads to fit flush,

d) Holddown post, NC tapes - numerical controlled tapes to machine the holddown post,

e) Holddown post bearing press - used to press the core holddown spherical bearing assembly into the holddown post bearing recess,

f) Skin panel hoisting tool - required to facilitate handling the large skin panels, Figure 5.2.8.4-1,

g) Skin panel subassembly hoisting tool - needed to handle skin panel subassemblies, Figure 5.2.8.4-2

2. Ring Frame Segment Subassembly:

a) Deep-ring segment subassembly fixture - needed to assemble bonded honeycomb web to inner and outer T-sections, see prior Figure 5.2.1.1-4,

b) Intermediate-ring segment subassembly fixture - similar to above, see prior Figure 5.2.1.1-5,

c) Deep-ring track router fixture - this fixture holds the ring face-sheets and provides a track to profile the sheets, prior Figure 5.2.1.1-3,

d) Intermediate-ring track router fixture - similar to above,

e) Deep-ring segment bonding fixture - this serves the purpose of holding the face sheets, Z-rings and honeycomb while the adhesive bonding material is being cured in the autoclave,

f) Intermediate-ring segment bonding fixture - similar to above,

g) Deep-ring segment handling tool - used to facilitate handling the ring segment,

h) Intermediate-ring segment handling tool - similar to above,

i) Intermediate-ring track router fixture with polyglycol chuck - this device provides a means of stabilizing the edges and holding one side of the honeycomb blank while the ring segment web cores are profiled and chamfered, see prior Figure 5.2.1.1-3,

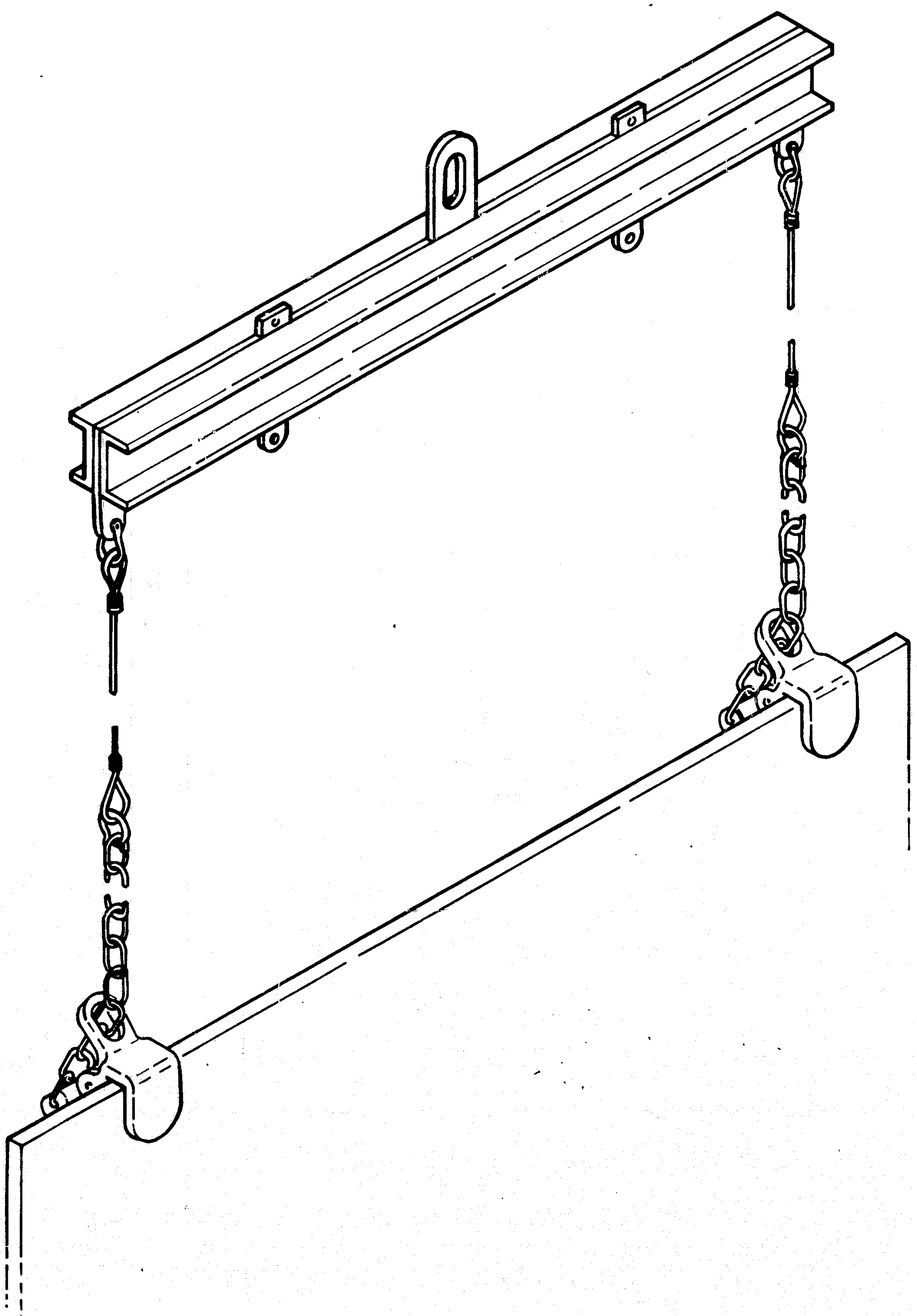


FIGURE 5.2.8.4-1 SKIN PANEL HOISTING TOOL

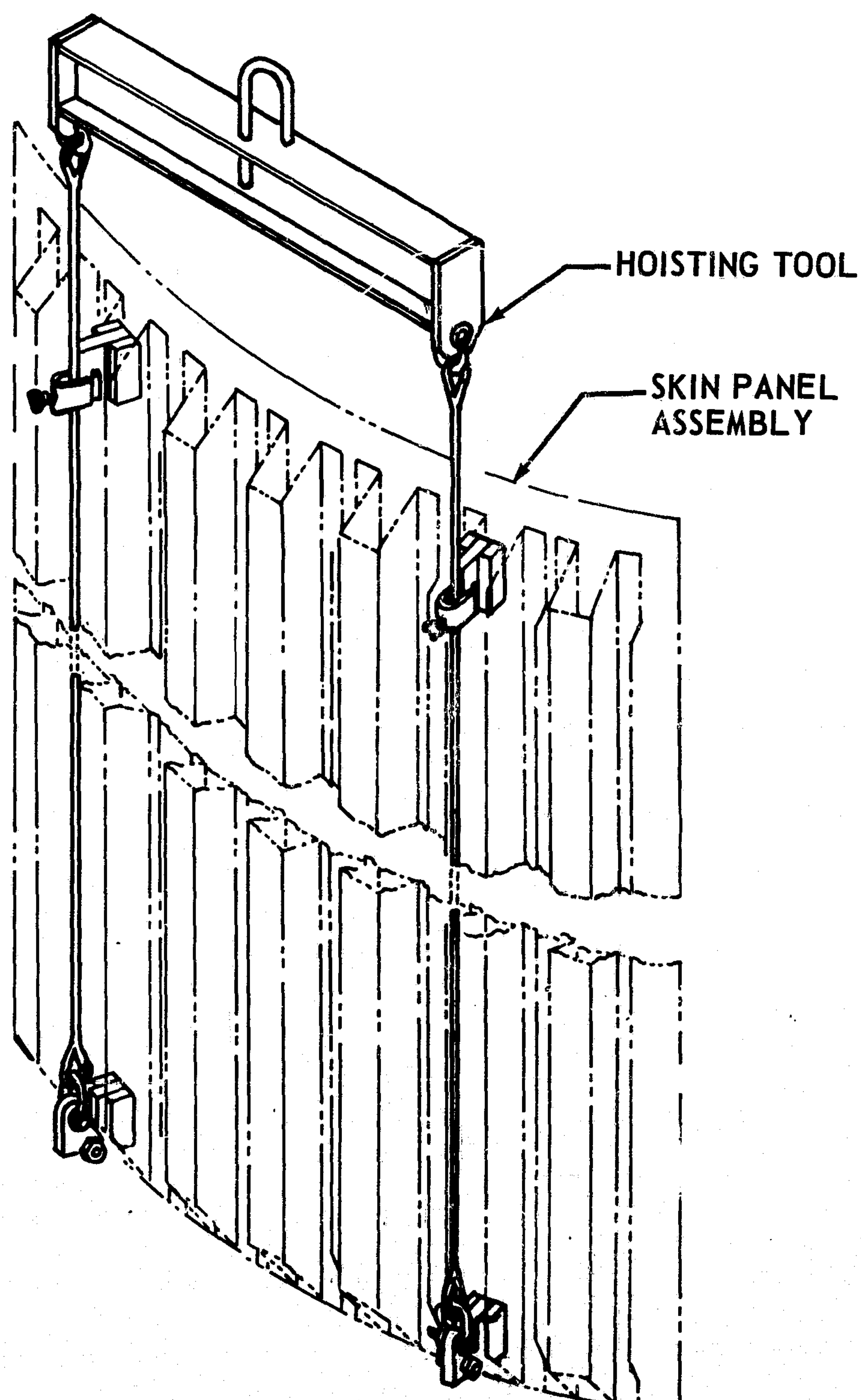


FIGURE 5.2.8.4-2 SKIN PANEL SUBASSEMBLY HOISTING TOOL

5.2.8.4 (Continued)

j) Deep-ring track router fixture - similar to above,

k) Ring frame web assembly handling fixture - used to move the web assembly, Figure 5.2.8.4-3,

l) Inboard and outboard T-cap handling fixture - used to move ring frame T-sections, Figure 5.2.8.4-4,

3. Interface Angle-Ring Subassembly, Interface Ring Segment Handling Tool - Needed for handling the interface ring segments;

b. Final Assembly Tools:

1. Final assembly fixture - to hold and locate the forward skirt subassemblies for fastening, see prior Figure 5.2.1.1-1,

2. Personnel platform - used to provide access to the forward skirt final assembly fixture,

3. Final assembly handling tool - used for lifting the completed forward skirt, see prior Figure 5.2.1.1-7,

4. Final assembly transportation trailer - used to provide a means for moving the forward skirt to the next position,

5. Inverting fixture - a trunnion mounted tool for inverting the forward skirt subsequent to assembly, see prior Figure 5.2.1.2-1,

6. Master gage - this will provide a standard for the interface hole pattern between the forward skirt and the payload or injection stage;

c. Miscellaneous Tools, miscellaneous detail tools are not individually identified;

d. Capital Equipment:

1. Forming:

a) Fifty-ton roll - a roll of this capacity is required to form the skin panels to contour,

b) Buffalo roll - this machine is needed to roll the Z-shape into the honeycomb edge closures of the bonded ring frame shear web,

c) Collet roll - the honeycomb edge closures are rolled to curvature in this machine,

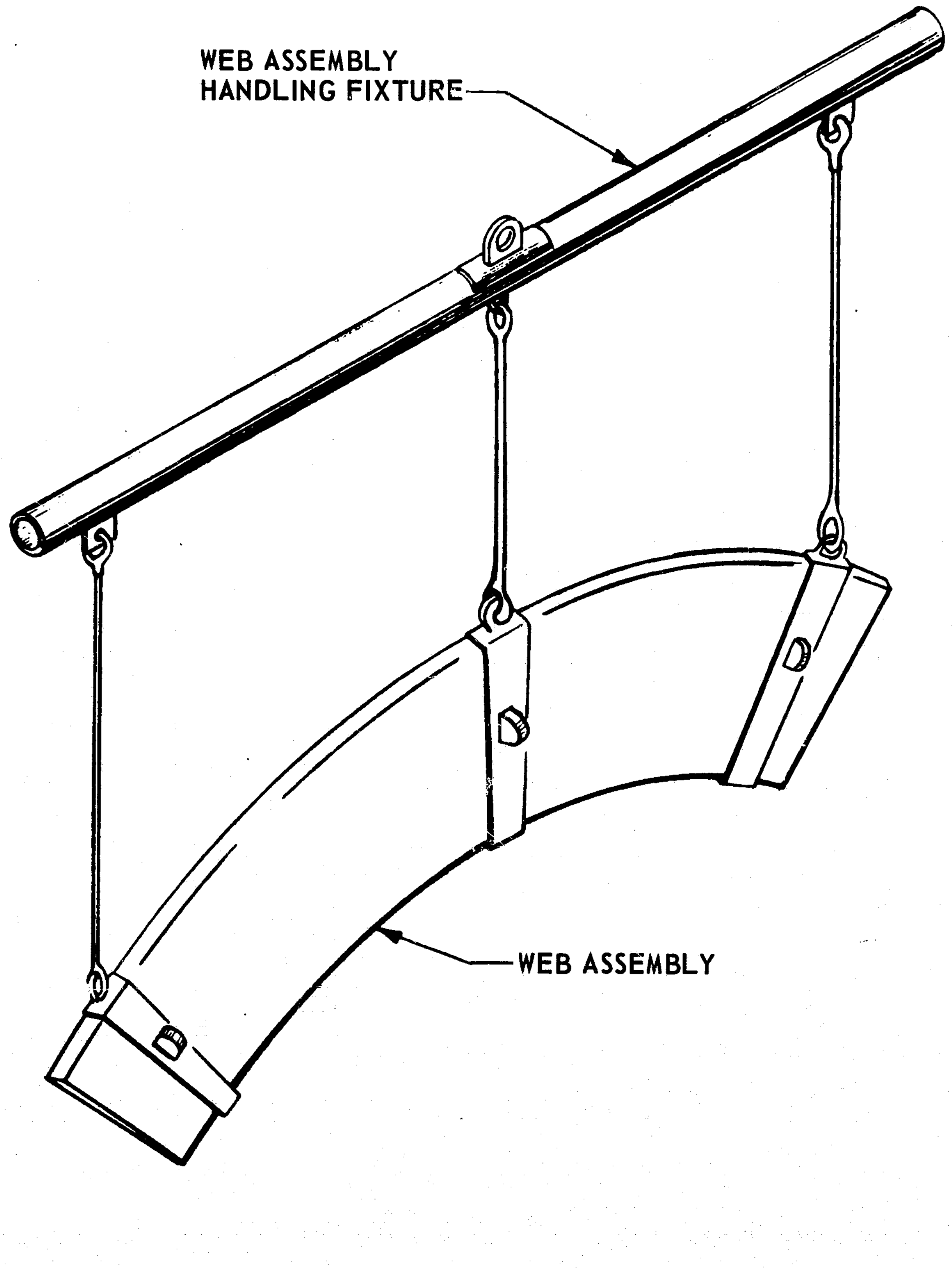


FIGURE 5.2.8.4-3 RING FRAME WEB ASSEMBLY HANDLING FIXTURE

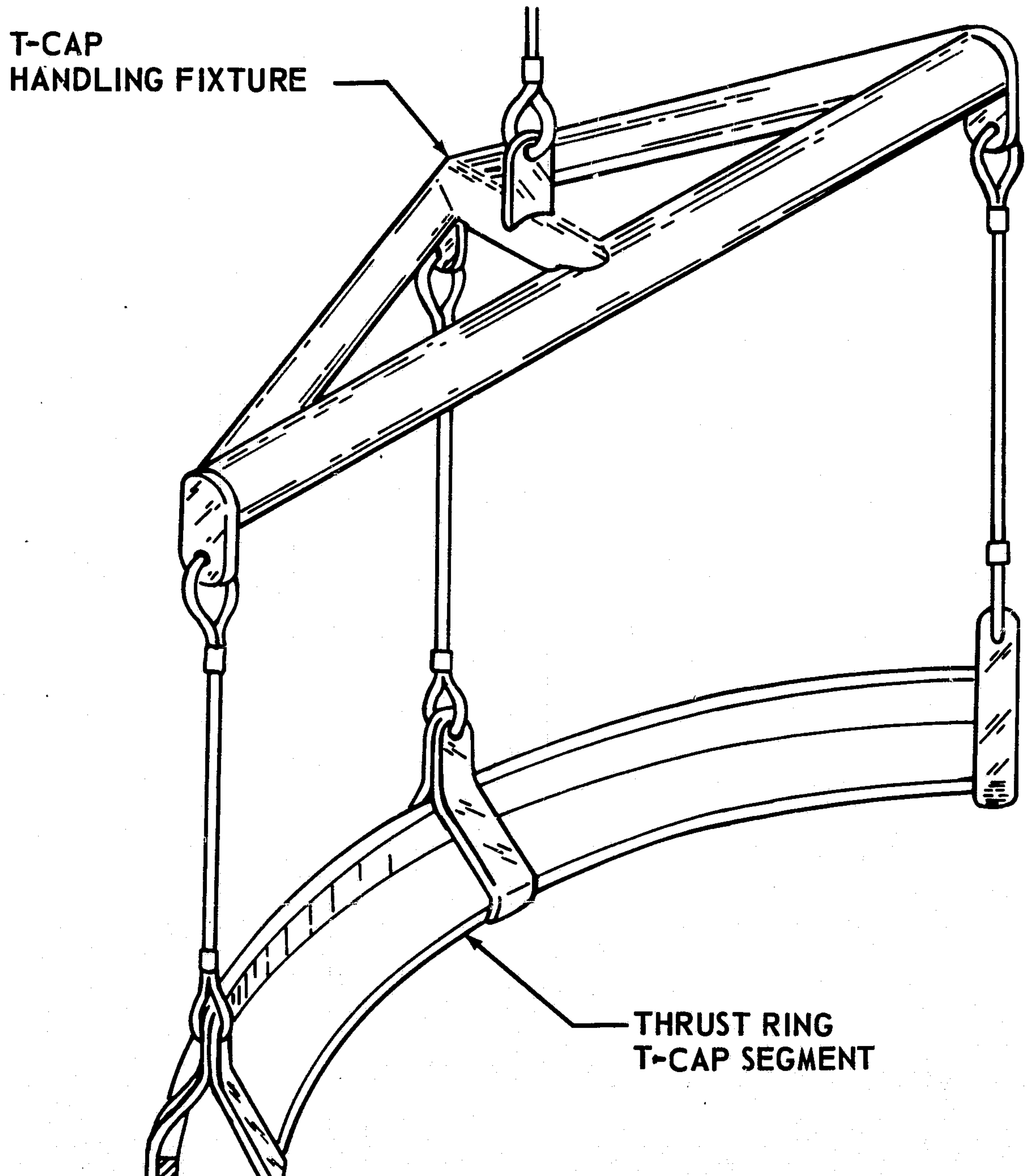


FIGURE 5.2.8.4-4 INBOARD AND OUTBOARD T-CAP HANDLING FIXTURE

5.2.8.4 (Continued)

d) Press - required to hot form the joggles in the ends of the hat sections,

2. Machining:

a) Band saw - needed to cut the skin panels and hat sections to length,

b) NC mill - used to machine holddown posts and other forgings,

c) Boring mill with 57-foot-diameter turntable - used to machine finish T-chords of the ring frames,

d) Pneumatic track router - needed to profile shear web face sheets,

e) Auto feed pneumatic drill - about 50 of these drills will be required for the forward skirt; these drills are used in conjunction with drill templates,

3. Heat Treating:

a) Furnace (40 by 40 by 18 feet with 705 degrees F. capacity) - required to heat treat forgings,

b) Autoclave (30 by 25 by 10 feet) - used to bond the ring frame webs,

4. Finishing:

a) Chemical cleaning line - this will include five, 26 by 10 by 5 feet tanks used for alkaline cleaning, deoxidizing, rinsing, and alodining detail parts,

b) Waterfall paint spray booth - a manual booth (30 by 10 foot opening) for spray-priming detail parts,

5. Handling — 30-ton overhead bridge crane is required for handling the forward skirt and other structures,

6. Fastening — Miscellaneous riveters to mechanically fasten parts.

Propellant Tank Assembly Tooling and Capital Equipment — The following paragraphs provide a brief description of the function of each identified tool and capital item. Tools, which are special purpose items designed specifically for the MLLV and AMLLV, are identified by the subassembly and assembly operation with which they are associated. Capital items, general purpose equipment is identified by function:

5.2.8.4 (Continued)

a. Subassembly Tools:

1. Bulkhead Tools:

a) Apex fixture, trim - to router trim apex gore sections,

b) Base fixture, trim - to router trim base gore sections,

c) Apex-to-base weld fixture - to hold base and apex gores for welding,

d) Meridian trim fixture - to router trim gore assemblies,

e) Meridian vacuum chuck - to hold gore assemblies to weld fixture,

f) Meridian weld fixture - a curved track to weld gore assemblies together,

g) Meridian assembly fixture - turntable with above vacuum chuck; base of head is also trimmed here,

h) Y-Ring and polar cap assembly fixture - a separate turntable to weld Y-ring and polar cap to bulkhead,

i) Bulge form die, base, - upper and lower bulkhead,

j) Bulge form die, base, - common bulkheads,

k) Bulge form die, apex, - all bulkheads,

l) Hoisting tool for gore - tubular frame for lifting,

m) Hoisting tool for bulkhead - tubular ring with 12 drops; also handles Y-ring,

n) Heat treat fixture base - to hold gore to contour during heat treating,

o) Heat treat fixture apex - to hold gore to contour during heat treating,

p) Autoclave fixture - to hold common bulkhead face sheets to honeycomb core for bond cure,

q) Autoclave - to provide heat and pressure to bond common bulkhead,

r) NC tapes - to machine weld lands on gores,

s) Y-Ring weld station - to weld billets together,

5.2.8.4 (Continued)

t) Personnel platform - polar cap to bulkhead weld operation,

u) Personnel platform - meridian weld operation,

v) Meridian test weld fixture - to set up welding fixture on test specimen,

w) Y-Ring to bulkhead test weld fixture - to set up welding fixture on test specimen,

x) Transporter - to move bulkhead,

y) Router fixture - to trim bulkhead skirt,

z) Bulkhead control gage - to check bulkhead contour,

aa) Picture frame for gores - to hold gores for storage before use,

ab) Master fixture - a gauge to check gore control,

ac) Blankets, chuck, - to maintain outside mold line (OML) of gores,

ad) Vacuum seal plates - to seal openings for vacuum seal,

ae) Holding shoes, gores, - base edge of gore assemblies are held to turntable of meridian station,

af) Common bulkhead test fixture - to leak test common bulkhead,

2. Baffle and cruciform detail tools:

a) DJ ring baffles - drill jig to drill ring baffles,

b) AF ring baffles - holds ring baffles for assembly,

c) SA ring baffles - holds ring baffles for drilling,

d) AF LOX cruciform baffle - common bulkhead cruciform baffle assembly,

e) AF LH_2 cruciform baffle - similar to above but for lower bulkhead assembly,

f) DJ cruciform assembly - to drill cruciform assembly, four required,

5.2.8.4 (Continued)

3. Cylindrical skin tools:

   a) K&T mill subbase and check - to hold skins during NC milling,

   b) Numerical tapes - for NC milling skin weld lands,

   c) Age form fixture - to permanently form LH_2 skin to contour,

   d) Age form fixture - to permanently form LOX skin to contour,

   e) Check fixture - to check contour after heat treat,

   f) Transportation dolly - to move skins,

   g) T-stiffener weld fixture - to weld T-stiffener to skins,

4. Miscellaneous tool — LOX tunnel cleaning booth - for cleaning inner tunnel prior to application of honeycomb and outer skin;

b. Assembly Tools:

1. Weld station - turntable,
2. Personnel platform - inside tank skin buildup,
3. Personnel platform - outside,
4. P.R. dolly - to move skin cylinder,
5. Hoisting tool - to lift skin onto turntable,
6. Transportation trailer - to move skins,
7. Transporter - to move all structures to VAB,
8. Skin shoes - to hold base edges of skins to turntable,
9. Drill jig, baffle installation - to drill baffle T's on assembly,
10. Router for skins - to mate edges of skins,
11. X-ray equipment - to inspect vertical welds,
12. Test weld fixture - to set up for welding skins,
13. Test weld fixture - to set up for welding Y-ring to skins, Figure 5.2.8.4-5,
14. External vacuum chuck - to hold skin in alignment,
15. Inverting fixture - to invert LOX tank,
16. Vertical skin welding/routing equipment - to route skins and perform skin welds,
17. Tunnel handling fixture - to emplace tunnels,
18. Drill jig for tie rods - to drill fitting attach holes,
19. Inverting fixture - to invert upper propellant tank section,
20. Hoisting tool - to handle skin details;

c. Miscellaneous tools, have been costed but are not individually identified;

d. Capital Equipment:

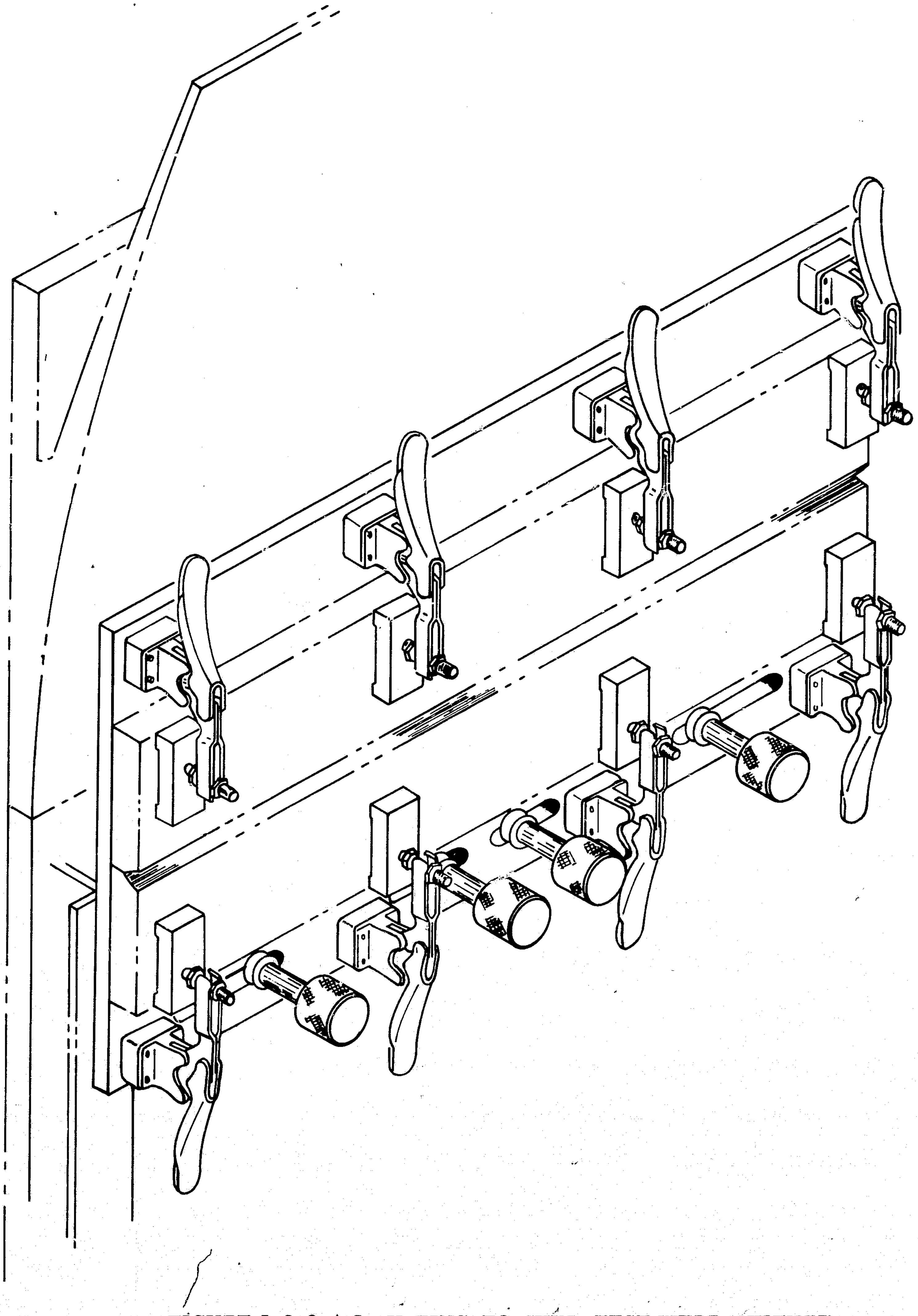


FIGURE 5.2.8.4-5 Y-RING-TO-SKIN, TEST WELD FIXTURE

5.2.8.4 (Continued)

1. Forming — a bulge form press will be required to form the baffle and cruciform details; it will occupy approximately 2000 sq. ft. and will weigh 20,000 pounds,

2. Machining:

   a) Router - two of these are required to trim gores and bulkhead skirts,

   b) NC mill - used to machine weld lands on skins and gores; also used to face the extruded tank T-stiffeners for welding,

   c) Router - one is required to trim skin edges on assembly,

3. Heat Treating:

   a) Autoclave - 80 by 80 by 30 feet, 500°F to bond face sheets to honeycomb on common bulkhead,

   b) Furnace - 40 by 100 by 18 feet, 750°F, used to age-form skins to contour and to heat treat gore sections after forming,

4. Welding — out-of-vacuum electron beam welding will be used where possible. Five of these units will be required for gore-to-gore and bulkhead-to-Y-ring welds. Another welder will be needed to weld T-sections to skins. A seventh welder will be needed in the VAB to weld tank skins together and to weld on bulkheads,

5. Handling — a 280-ton overhead crane will be required for general purpose lifting in the VAB,

6. Finishing — 50 by 12 by 8 foot chemical cleaning and conversion coating tanks for skins and gores; four tanks required.

Aft Skirt Tooling and Capital Equipment — A brief description of the function of each tool and capital item is given in the following paragraphs. Tools designed specifically for the MLLV and AMLLV are identified with the associated subassembly fixture. Capital items and general purpose equipment are identified by function.

a. Subassembly Tools:

1. Skin panel subassembly:

   a) Skin panel subassembly fixture - used to build the complete subassembly from skins, hat section stringers, and outer splice-plates, Figure 5.2.4.1-1,

5.2.8.4 (Continued)

b) Personnel platform - provides overall access to the skin panel subassembly fixture, Figure 5.2.4.1-2,

c) Skin panel assembly hoisting tool - required to remove the place subassembly on transport/storage dolly, Figure 5.2.4.1-3,

d) Transport/storage dolly - used to transport subassemblies from subassembly to major assembly fixture,

e) Hat section drill plates - holds hat sections on skin and locates fastener holes,

f) Skin panel hoisting tool - required to handle large skin panels prior to assembly,

2. Thrust and intermediate-ring subassembly:

a) Thrust ring segment subassembly - fixture required to assemble bonded honeycomb web to inner and outer T-chords, Figure 5.2.4.1-4,

b) Intermediate-ring segment subassembly fixture - similar to above,

c) Thrust-ring track router fixture - used to hold the face sheets while the correct profile is routed around their edges; also provides the correct profile track for the router to follow,

d) Intermediate-ring track router - similar to above,

e) Thrust-ring segment bonding fixture - holds the face sheets, Z-sections, and honeycomb while the adhesive bonding material is being cured in the autoclave,

f) Intermediate-ring bonding fixture - similar to above,

g) Thrust-ring track router fixture with polyglycol chuck - provides a means of stabilizing the edges of the honeycomb during the routing operation,

h) Intermediate-ring track router fixture - same as above,

i) Thrust-ring web assembly hoisting tool - used to lift web assembly,

j) Intermediate-ring web assembly hoisting tool - same as above,

k) Miscellaneous access hole templates - used to locate holes (i.e., LOX and fuel fitting holes) in thrust-ring web assembly,

5.2.8.4 (Continued)

1) Miscellaneous access hole templates - same as above for intermediate ring,

3. Thrust Post:

a) Numerical control tapes for milling thrust posts,

b) Handling fixture - used to move finished posts from mill to major assembly fixture;

b. Major Assembly Tools:

1. Major assembly fixture - to hold and locate all aft skirt components prior to fastening,

2. Personnel platform - provides access to all parts of the major assembly fixture,

3. Major assembly/transport dolly - used to move the completed structure to the vertical assembly station;

c. Miscellaneous Tools — the different items of miscellaneous tools and their costs have been identified but are not included in this list;

d. Capital Equipment:

1. Forming:

a) Fifty-ton roll - a roll of this capacity is required to form the skin panels to contour,

b) Buffalo roll - this machine is needed to roll the Z-shape into the honeycomb edge closures of the bonded ring frame shear web,

c) Collet roll - the honeycomb edge closures are rolled to curvature in this machine,

d) Press - required to hot-form the joggles in the ends of the hat sections,

2. Machining:

a) Band saw - needed to cut the skin panels and hat sections to length,

b) NC mill - used to machine thrust posts and other forgings,

5.2.8.4 (Continued)

c) Boring mill with 57-foot, (72) diameter turntable - used to machine finish T-chords of the ring frames,

d) Pneumatic track router - needed to profile shear web face sheets,

e) Auto feed pneumatic drill - about 25 of these drills will be required for the skirt; these drills are used in conjunction with drill templates,

3. Heat Treating:

a) Furnace (40 by 40 by 18 feet with 750°F capacity) - required to heat treat forgings,

b) Autoclave, 500°F (30 by 25 by 10 feet) - used to bond the ring frame webs,

4. Finishing:

a) Chemical cleaning line - this will include five, 30 by 15 by 7 feet tanks; they will be used for alkaline cleaning, deoxidizing, rinsing, and conversion coating detail parts,

b) Waterfall paint spray booth - a manual booth (30 by 10-foot opening) for spray-priming detail parts,

5. Handling:

a) Crane - a 30-ton overhead bridge crane is required for handling the aft skirt and other structures,

b) Jacks - hydraulic jacks for lifting the structure to allow removal of supports.

Centerbody Plug Tooling and Capital Equipment — All major tools and equipment required for the fabrication of the centerbody plug structure are included in this section. A brief description of the function of each tool is also given.

a. Subassembly Tools:

1. Upper LH_2 Manifold Assembly Tools — listed below are the tools required for assembly of the upper LH_2 manifold ring. This list includes some of the detail fabrication tooling:

a) Ring segment handling tool - this tool is used for placing ring segments in assembly fixture,

5.2.8.4 (Continued)

b) Upper manifold weld fixture - this fixture is used to hold segment rings together for welding,

c) Trim fixture, manifold segments - used for manifold segment weld end preparation,

d) Manifold handling tool - used to remove manifold ring to transportation trailer and assembly to outer face skin ring,

e) Heat treat fixture - used to hold manifold segments during heat treat,

2. Lower LH_2 manifold assembly tools:

a) Ring segment handling tool - this tool is used for hoisting ring segments to assembly fixture,

b) Lower LH_2 manifold handling tool - used to move manifold ring to transportation trailer and to position manifold onto outer face skin ring,

c) Lower manifold weld fixture - this fixture is used to hold segments for welding,

d) Trim fixture, ring segments - used to prepare ends after roll-forming segments,

e) Heat treat fixture - used to hold ring segments during heat treatment,

3. Base plug - outer-face skin ring:

a) Track router fixture - used in trimming skin segments prior to ring assembly,

b) Skin segment hoisting tool - used to hoist skin segments to transportation dolly and onto assembly fixture,

c) Weld fixture - used to hold skin segments for weld operations,

d) Skin-ring hoisting tool - used to transfer skin ring to transportation dolly and to assemble fixture,

e) Line welder - used to make inclined skin seam welds, Figure 5.2.8.4-6,

f) Personnel platforms,

g) Trim fixture - used to trim skin segments prior to ring assembly,

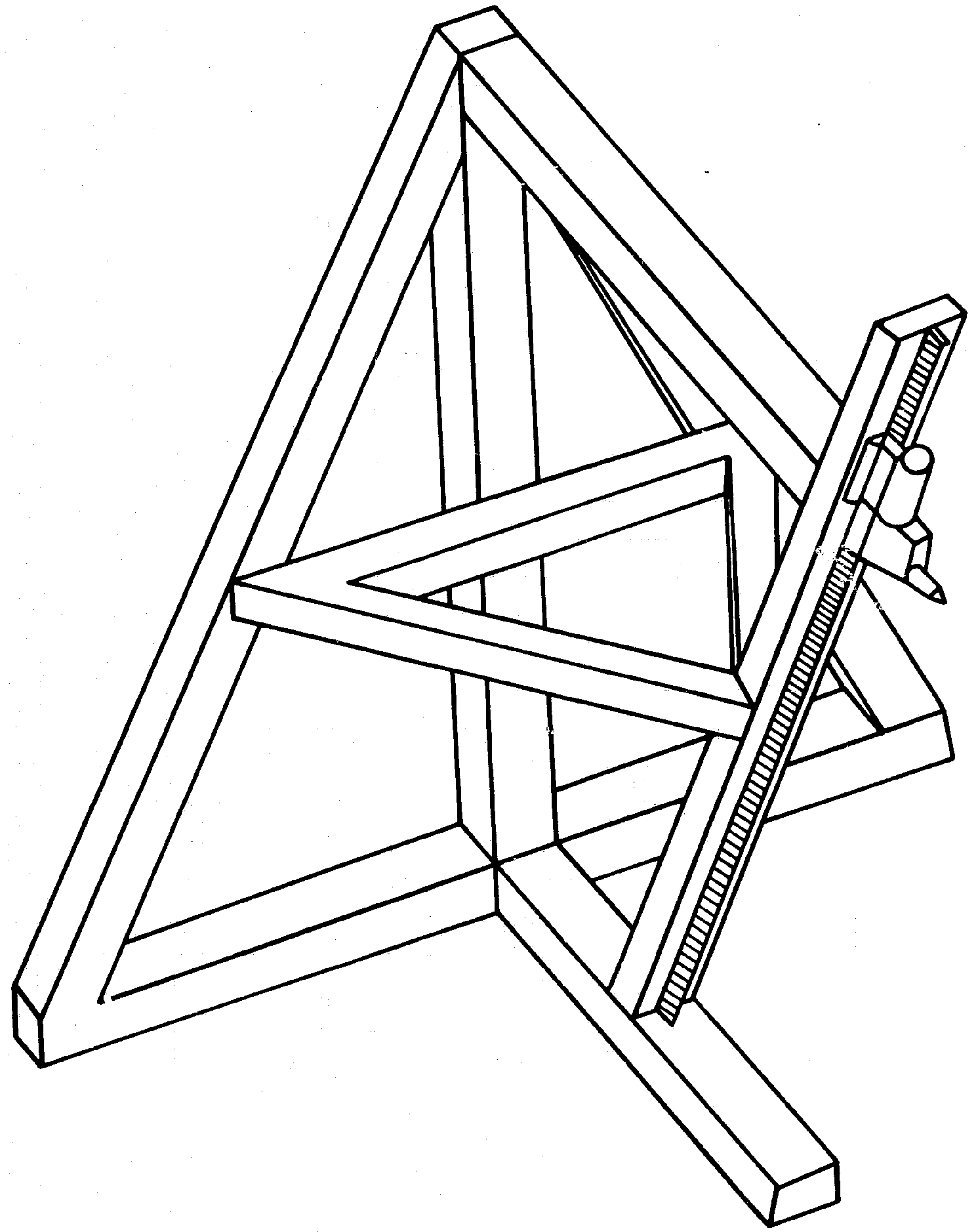


FIGURE 5.2.8.4-6 LINE WELDER

5.2.8.4 (Continued)

h) Heat treat fixture - used to hold ring segments during heat treat,

4. Base plug - bulkhead-ring assembly tools:

a) Ring segment hoisting tool - this tool is used to transfer ring segment to transportation trailer and assembly fixture,

b) Weld fixture - used to hold ring segments during weld operation,

c) Heat treat fixture - used to hold rings segments during heat treat,

d) End trim fixture - used to prepare ring segment ends for welding,

5. Base structure bulkhead:

a) Turntable - bulkhead fabrication,

b) I-beam hoisting tool - used to move I-beams to assembly fixture,

c) Hoisting tool, gore sections - used to place gore sections on assembly fixture,

d) Weld and trim fixture - used to hold I-beam framework for welding,

e) Meridian welder - used to weld gore sections,

f) Polar cap welder - used during installation of polar cap,

g) Personnel platform - used during hand weld of I-beam framework,

h) Transportation dolly, bulkhead gores - used to move the bulkhead gores to the assembly station,

i) Transportation dolly, I-beam frames - used to move the I-beam frames to the assembly station,

b. Final Assembly Tools:

1. Bonding fixture - backup structure,
2. Holding fixture - regenerative tube installation,
3. Personnel platforms - layup sections of honeycomb,
4. Personnel platforms - tube installation,
5. Inverting tool - conical structure,
6. Transportation dolly - major assembly,
7. Handling tool - base bulkhead,
8. Handling tool - base plug,
9. Autoclave - backup structure,
10. Automatic feed pneumatic drill - final assembly;

5.2.8.4 (Continued)

c. Miscellaneous tools — these tools are coded according to function but cannot be classified as dies, jigs, fixtures, or mechanical equipment:

1. Drill tools - special drill bits, reamers, counterborers, etc.,

2. Form cutting tools - special cutting tools required for use on lathes, milling machines, etc.,

3. Optical tools - these tools are mounting devices for optical instruments which are used to optically inspect other tools,

4. Master models - these tools are accurate models of formed production parts and are used for making part models and for setting or making transfer gages,

5. Standard tools - tools not limited to specific parts or assemblies such as tube bending tools, burring tools, wrenches, etc.;

d. Capital Equipment:

1. Forming:

a) Buffalo roll - this machine is used to form the I-beam stringer segments of the base structure bulkhead,

b) Bulge form die, base gore - metal form die used to form base gore segments of base bulkhead,

c) Bulge form die, intermediate gore - metal form die used to form intermediate gore segments of base bulkhead,

d) Bulge form die, apex gore - metal form die used to form apex gore segments of base bulkhead,

e) Bulge form die, inner face-skin segment - metal form die used to form inner face-skin ring segments of base plug,

f) Bulge form die, outer face-skin ring segment - metal die used to form the outer face-skin ring segments of the base plug;

g) Roll form die, upper manifold ring segment - used to form ring segments of the base plug upper manifold ring,

h) Roll form die, lower manifold ring segment - used to form ring segments of the base plug/lower manifold ring,

5.2.8.4 (Continued)

2. Machining:

a) Track router - used for trimming inner and outer face skin segments,

b) Track router - used for trimming outer-face skin assembly of the base plug,

c) Auto feed pneumatic drills - these drills will be required in the mechanical fastening of the base bulkhead to the base plug,

d) Form mill - used to machine the contour surface of the upper and lower manifold ring segments,

e) Inclined surface grinder - used to remove weld bead from inside weld seam of outer-face skin ring prior to bonding honeycomb panels in place,

3. Heat Treating:

a) Heat treat furnace - (40 by 40 by 18 feet) used to heat treat manifold ring segments and skin rings,

b) Autoclave furnace - (80 by 80 by 30 feet) used in bonding honeycomb structure of the base plug,

4. Finishing — 50 by 12 by 8 foot chemical cleaning and conversion coating tanks for skins, manifold segments, etc.

Final Assembly Tooling and Capital Equipment — A brief description of the function of each tool and capital item follows. Unless otherwise noted, all tools are designed specifically for the final assembly of the MLLV and AMLLV core stage. Capital items and general purpose equipment are identified by function.

a. Vertical Assembly Tools — The following tools are required to assemble the forward and aft skirts to the tank assembly:

1. Forward handling ring - used to lift the forward and aft skirts, Figure 5.2.6.2-1,

2. Forward skirt adapters - used to adapt forward skirt to forward handling ring, Figure 5.2.6.1-1,

3. Aft skirt adapters - used to adapt aft skirt to forward handling ring, Figure 5.2.6.1-1,

4. Vertical alignment checking tool - used to check alignment of forward skirt relative to tanks, Figure 5.2.6.1-2,

5.2.8.4 (Continued)

5. Forward skirt alignment adjustor - used to adjust skirt relative to Y-ring, Figure 5.2.6.1-3,

6. Forward skirt Y-ring drill jig - used to drill fastener holes in forward skirt and Y-ring, Figure 5.2.6.1-5,

7. Forward interface master gauge - locates holes for interfacing forward skirt to injection stage,

8. Forward skirt circumferential ring - attaches to upper SRM mounts and provides a track for rotation in the horizontal position and interfaces adapter plates to forward skirt assembly,

9. Aft skirt circumferential ring - provides rear support for rotation in horizontal position and supports trunnions during laydown operation,

10. Vertical positioners (aft bulkhead Y-ring) - locates aft skirt relative to the aft bulkhead Y-ring, Figure 5.2.6.2-3,

11. Rotational positioners (aft bulkhead Y-ring) - aligns aft skirt relative to the aft bulkhead Y-ring, Figure 5.2.6.2-4,

12. Aft skirt Y-ring drill jig - used to locate and drill fastener holes in aft skirt, Figure 5.2.6.2-5,

13. Personnel platform - provides access to entire vertical surface during assembly,

14. Vertical brush assembly - used to etch and sand the tank surface prior to the foam-applying operation,

15. Foam nozzle bank - used to apply foam to the outer tank surface, Figure 5.2.6.2-6,

16. Paint nozzle bank - used to apply paint to the finished tank,

17. Tank transporter - provides transportation for complete main core stage,

18. Hydraulic power supply - supplies power to jacks and steering motors on transporter,

19. Circumferential ring (real trusswork) - holds truss posts in proper position for mounting to aft skirt,

20. Circumferential ring handling tool - fastens to circumferential rings and lifts entire trusswork to aft skirt trusswork fittings,

5.2.8.4 (Continued)

21. Centerbody plug handling ring - lifts centerbody plug into position with trusswork fittings,

22. Dummy engine actuators - holds engines during installation on stage,

23. Engine transporter - used to hold, transport, and locate engines in place on the core stage while it is in the horizontal position, Figures 5.2.6.5-1 and 5.2.6.5-2.

b. Capital Equipment:

1. Assembly:

   a) Keller air drills (25 required) - drill holes in Y-ring interface points,
   b) Air compressor - for foaming and painting operations,
   c) Blower/Heater - for use during foaming and sanding operations,

2. Handling: Crane, 300-ton - lifts tank assembly out of assembly station and on to transporter.

Main Stage Systems Fabrication Capital Equipment — This section covers the capital equipment for systems fabrication. The systems include the mechanical/propulsion system and the electrical/electronic system. Each of these major systems is divided into its subsystems. These subsystems are identified and the equipment list for their fabrication is identified. The floor space and tools necessary to perform electrical/electronic fabrication are also shown.

Mechanical/Propulsion Systems Capital Equipment — Individual test stations, a total of 14, will be established to provide separate test systems for the various fluid systems. A dual station concept will be utilized to provide continuous testing and to allow for maintenance and calibration. The test stations will be designed around a walk-in test cell and test rooms concept with an associated test rack. The test equipment required to perform the tests will be construed to be off-the-shelf buy type where practicable and will be mounted in standard rack type cabinets. This arrangement will provide for calibration, maintenance, and modification to be performed in an area other than the test area. Pneumatic testing anticipated up to 3500 psig will be controlled from the station rack having a panel(s) containing the necessary manual valves, pressure regulators, relief valves, and pressure gages to perform the component test from outside the test cell. The pneumatic panels will be a make item by necessity and will allow for ease of calibration, maintenance, and modification.

The electrical checks on stage components (expected to be limited to continuity, insulation resistance and timing) will be performed by utilizing an electrical test panel in the station rack, allowing the patching of tests from the various rack mounted equipment. These panels will also be make items.

5.2.8.4 (Continued)

Test fixtures for the component testing will be held to the minimum by the use of individual component holding/testing fixtures to allow for quick set-up and connection to the test rack/test cell feed-through panel.

A separate test station will be established for hydrostatic testing of the stage cylinders and ducts. Hydrostatic testing anticipated up to 7000 psig will be controlled from the station racks having a panel containing the necessary manual valves, pressure regulators, relief valves and pressure gauges to perform the component test from outside the test cell.

The test equipment required to perform the tests will be constrained to be off-the-shelf buy type where practicable and will be mounted in standard rack type cabinets.

Due to the relevant size of some of the major components, special holding fixtures will be required to handle, position, and hold down the components.

The stations must also be capable of:

a. Hot alkaline clean;
b. Tap water rinse, 160^{o}F;
c. Nitrogen purge of rinsed tank.

The required hardware and equipment for the propulsion/mechanical are shown below:

Type	Quantity
Lath 9" x 48"	1
Lath 16" x 84"	1
10" Tool Maker Lathe	1
4" bar horizontal boring mill	1
6" cap. centuless grinder	1
8 x 24" universal grinder	1
24" x 77" surface grinder	1
I.D./O.D. grinder	1
6' arm radial drill	1
3' arm radial drill	1
2 spindle x 1/2 cap drill	1
L/O table	1
Shear 1/4 x 4'	1
Brake 1/2" x 12'	2
Brake 1/2' x 8	2
75-ton mechanical press	1
12' x 3/8" cap roll	1
#1 buffalo roll	1

5.2.8.4 (Continued)

Test equipment for the engine tests will consist of five GN_2 control stations, five electrical test consoles (caster mounted) and five throat plugs. These units will be used for supply, control, and monitor of engine systems under test.

Measurement and telemetry equipment will consist of transducers and sensors; such as pressure, temperature, and strain; multiplexers and RF power assemblies.

Electrical/Electronic Test Equipment — The electrical/electronic test equipment required for the test stations are as shown below:

a. Signal Conditioner Test Station:

1. Control panel,
2. Power supplies 0-10 VDC, 0-50 VDC,
3. Vacuum tube volt meter (VTVM),
4. Decade box;

b. Vibration Test Station:

1. Shaker head,
2. Shaker exciter amplifier,
3. Oscillator,
4. Accelerometer
5. Accelerometer ref. std.,
6. Power supply 5 VDC,
7. VTVM;

c. RF Test Station:

1. Test coder,
2. TM signal generator,
3. Command test panel,
4. Destruct system controllers test panel,
5. Power supply 28 VDC (2 required),
6. Impedance bridge,
7. Load bank,
8. Oscilloscope,
9. Audio oscillator,
10. VTVM;

d. Telemetric RF Test Station:

1. RF power amplifier, frequency modulation monitor,
2. Test control panel, RF switch and 6.3 VDC power panel,
3. TLM spectrum analyzer, RF spectrum analyzer,
4. TLM signal generator, PCM simulator, TLM receiver,
5. Wave analyzer, wattmeter attenuator, B+ modulator and noise generator (three each),

5.2.8.4 (Continued)

6. VTVM, power supply 5 VDC, oscilloscope, pulse generator, input and timer, power supply 0-500 VDC;

e. PCM/FM Test Station:

1. Data control panel, B+ modulator and noise generator,

2. Linear sweep generator, correlator panel, test control panel, power supply, digital signal simulator panel, FM demodulator, wattmeter attenuator,

3. PCM bit synchronizer, TEK 565 scope,

4. TLM receiver, digital sensor simulator panel precision D/A convertor, audio oscillator,

5. VTVM decode resistor and capacitor, load bank,

6. Power supply 5 VDC, square wave generator, counter and power supply, 28 VDC;

f. Pressure Transducer Test Station — VTVM, regulator valve, gage 0-1500 psia, power supply 10 VDC and 25 VDC, 100K ohm resistor;

g. On-Board Computer Test Station — Checkout control panel;

h. Antenna Test Station:

1. VHF signal generator, test control panel,
2. Power oscillator, VHF signal oscillator,
3. Radio interference meter, power oscillator; VTVM power supply, wattmeter RF power meter and load bank;

i. Instrumentation Test Station — EBW control and monitor test panel, Rall Control Electronics, test panel inertial sensor test panel;

j. Acoustic Test Station — VRMS meter, calibrated sound driver, VTVM oscillator, power supply.

5.2.8.5 Main Stage Capital Equipment Costs

Where possible, costs of equipment were obtained from existing cost lists for equipment. When lists are not made available the cost is factored from actual equipment costs on S-IC and other programs.

Equipment costs include:

5.2.8.5 (Continued)

a. Estimated delivered cost;
b. Equipment installation;
c. Equipment engineering support.

Equipment costs are for facilities type, purchasable equipment and installations. Special handling fixtures, jigs, tooling and data acquisition equipment are not included. The support equipment for post manufacturing and stage checkout area cost is estimated to be $10,000,000. This is based on actual costs for S-IC facilities at Michoud.

Associated with the equipment costs, (nonrecurring) are costs for equipment maintenance (recurring). Equipment maintenance cost is based on a percentage of the total estimated maintenance cost. The percentage used is based on individual judgment, depending on the quantity and type of equipment in the areas considered, Table 5.2.8.5-I.

TABLE 5.2.8.5-I MAIN STAGE MANUFACTURING EQUIPMENT COST SUMMARY - AMLLV AND MLLV

AREA	MAIN STAGE NON-RECURRING EQUIPMENT		MAIN STAGE RECURRING $/YR EQUIP. MAINT.	
	AMLLV	MLLV	AMLLV	MLLV
Main Stage Mfg. Bldg.	$42,342,000	$40,316,000	$1,984,000	$1,890,000
Vertical Ass'y Building	4,594,000	4,144,000	*219,000	208,000
Post Mfg. and Checkout	*300,000	*300,000		
Office	1,586,000	1,586,000		
TOTALS	$48,822,000	$46,346,000	$2,203,000	$2,098,000

*Based on the S-IC, the cost of the GSE would be $10,000,000 for a total equipment of $10,300,000. Maintenance of the GSE (primarily data acquisition equipment) is not reflected in the equipment maintenance cost.

Further analysis of the main stage costs in Table 5.2.8.5-I are shown in Tables 5.2.8.5-II and -III. These latter tables further define both the costs of the main and injection stage equipment in Table 5.2.8.5-II, and the costs of the vertical assembly building, post manufacturing and checkout and office building equipment, in Table 5.2.8.5-III.

TABLE 5.2.8.5-II MLLV AND AMLLV MAIN AND INJECTION STAGE MANUFACTURING EQUIPMENT

AREA	SQUARE FEET	EQUIP. DOLLARS	$/SQ. FT. EQUIP.	REMARKS
Bldg. Shell Low Bay	2,790,000			*2,700,000
Bldg. Shell High Bay	250,000			* 200,000 sq. ft.
Skin and Core Fab.	320,000	12,800,000	40.00	
Rework and Modification	150,000	6,000,000	40.00	*135,000 sq.ft. $5,400,000
Chemical Clean	67,500	4,725,000	70.00	* 65,000 sq.ft. $4,550,000
Major Clean	22,500	1,125,000	50.00	* 18,000 sq.ft. $ 900,000
Minor Assembly	500,000	4,500,000	9.00	*400,000 sq.ft. $3,600,000
Major Assembly	250,000	2,500,000	10.00	*200,000 sq.ft. $2,000,000
Major Paint	45,000	675,000	15.00	* 38,325 sq.ft. $ 575,000
Elect./Electronic	50,000	750,000	15.00	
Horizontal Instl.	50,000	300,000	6.00	
Component Test	180,000	12,600,000	70.00	
Subsystem Test	70,000	1,750,000	25.00	
Production Control	100,000	5,000,000	50.00	Equip. dollars includes primary utilities, heat, air conditioning and power
Non-Destruct Test	25,500	450,000	20.00	
Measurement Control	15,000	375,000	25.00	
Mfg. Dev. Lab	15,000	1,050,000	70.00	
Equip. Maintenance	40,000	600,000	15.00	
Plant Services	40,000	120,000	3.00	
Mock Up	40,000	5,000	.125	
Receiving and Inspection	60,000	180,000	3.00	
Shipping	37,500	50,000	1.35	
Whse. and Stores	450,000	900,000	2.00	
Support Facilities	500,000			
EQUIP. MAINTENANCE/YR.				
AMLLV	$2,656,000			
MLLV	$2,520,000			
TOTAL AMLLV	$56,255,000			
TOTAL MLLV	$53,755,000			

* Floor Space and Equipment dollars for the MLLV are the same as the AMLLV except where shown by asterisks.

TABLE 5.2.8.5-III MLLV AND AMLLV MAIN AND INJECTION STAGE MANUFACTURING SUPPORT AREAS EQUIPMENT

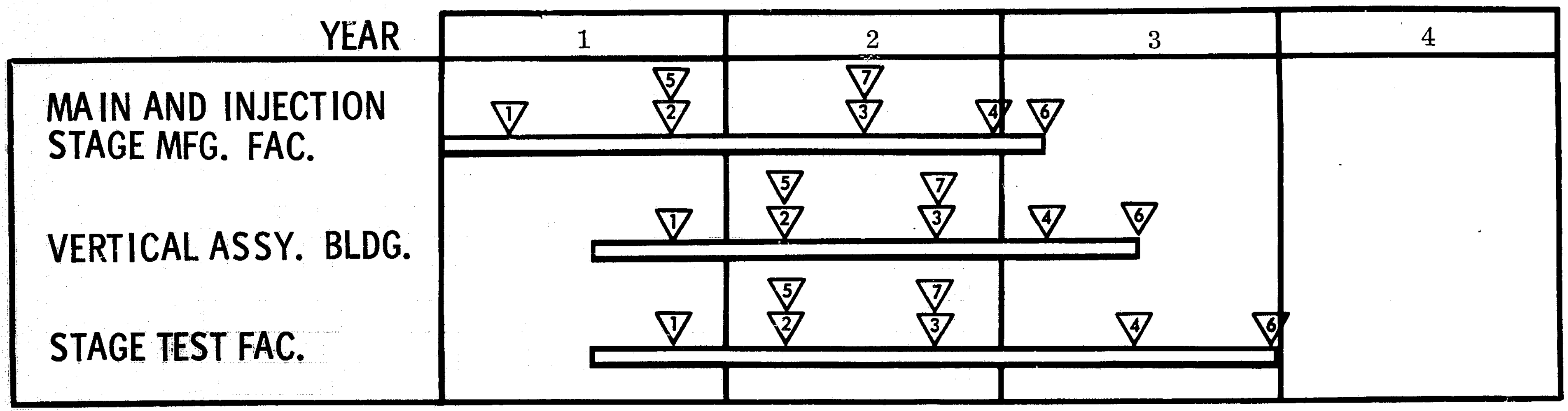
AMLLV	AREA SQ. FT.	EQUIP. DOLLARS	$/SQ. FT. EQUIP.	MAINT./YR. EQUIP.
Vertical Assembly Building	87,500	$6,125,000	70.00	$ 2,656,000
Post Mfg. and Stage Test	50,000	400,000	8.00	50,000
Office	650,000	$2,115,000	3.25	$ 165,000
MLLV	**AREA SQ. FT.**	**EQUIP. DOLLARS**	**$/SQ. FT. EQUIP.**	**MAIN./YR. EQUIP.**
Vertical Assembly Building	79,000	$5,525,000	70.00	$2,520,000
Post Mfg. and Stage Test	50,000	$ 400,000	8.00	$ 50,000
Office	650,000	$2,115,000	3.25	$165,000

5.2.8.6 Main and Injection Stage Manufacturing Facilities

The facilities will provide the necessary space, equipment, utilities and support to fabricate, assemble and check out the main and injection stages plus liquid engine manufacturing. Figure 5.2.8.6-1 illustrates the manufacturing facility, brick and mortar and equipment timeline. Figure 5.2.8.2-2 presents the main stage and injection stage manufacturing facility layout.

The manufacturing complex will be comprised of four buildings or areas:

a. Core and injection stages fabrication;
b. Vertical assembly building;
c. Post manufacturing and stage checkout;
d. Office building.



1 DESIGN CRITERIA COMPLETE

2 DESIGN 30% COMPLETE CONSTRUCTION START

3 DESIGN COMPLETE

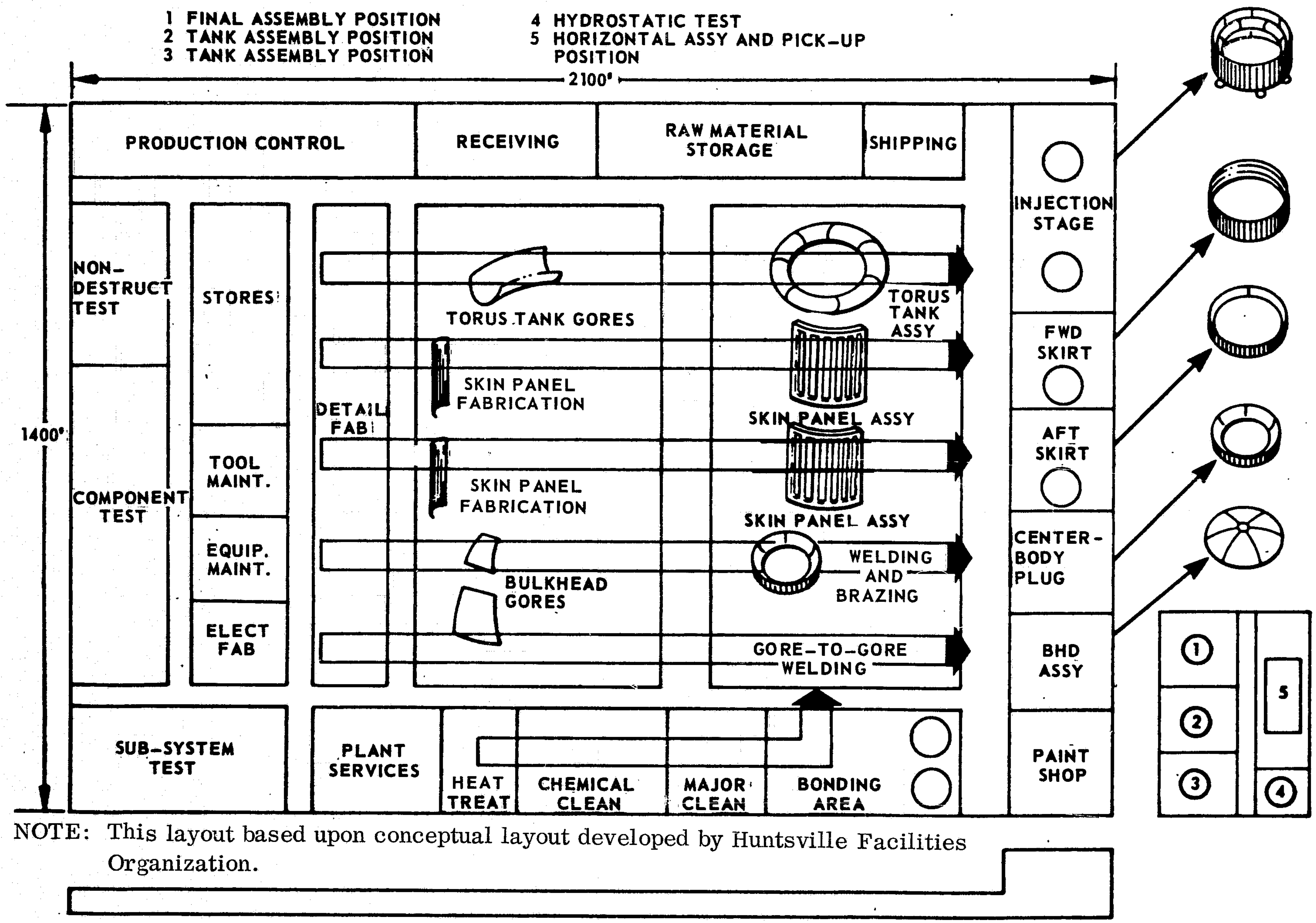
4 CONSTRUCTION COMPLETE

5 LONG LEAD EQUIP IDENTIFIED AND ORDERED

6 EQUIPMENT INSTALLED

7 STD EQUIPMENT ORDERED

FIGURE 5.2.8.6-1 MANUFACTURING FACILITY, BRICK MOTAR EQUIPMENT



NOTE: This layout based upon conceptual layout developed by Huntsville Facilities Organization.

FIGURE 5.2.8.6-2 MAIN AND INJECTION STAGE MANUFACTURING FACILITY

5.2.8.6 (Continued)

The AMLLV and MLLV main and injection stage building will contain low-bay and high-bay areas. The AMLLV low-bay will have a clear truss height of 40 feet and cover approximately 2,790,000 square feet. This area is 2,700,000 for the MLLV. Basic manufacturing, minor assembly, labs, component testing, cleaning, painting, shipping, receiving and support facilities will be housed in this area.

The AMLLV high-bay will have a clear truss height of 125 feet and cover approximately 250,000 square feet. For the MLLV this area is 200,000 square feet. This area will be used for assembly of large components, such as bulkheads and skirts, and final assembly of injection stages.

The AMLLV vertical assembly building will have a clear truss height of 250 feet and cover 87,500 square feet. The MLLV floor space is 79,000 square feet. Space is provided for two tank assembly areas, one hydrostatic tank test area and one final assembly area.

The post manufacturing checkout facilities for either the AMLLV or MLLV will provide areas for one core stage and one injection stage, with adequate room for data acquisition and support equipment, total area of approximately 50,000 square feet with 100-foot clear truss height. The office building for either the AMLLV or MLLV will provide 650,000 square feet.

Costs shown are for basic steel and concrete structures with utilities and services included. Additional costs for some of the special areas are also shown.

The manufacturing facilities for the MLLV are the same as the AMLLV. The only change would be a reduction in size of some of the assembly areas. The major component assembly, the minor assembly, the vertical assembly would be reduced approximately 20 percent. The engine manufacturing facilities and office areas would require the same space.

Equipment costs would reduce by a small percentage, as the only change would be physical size of some of the machines and fixtures.

Manufacturing Facilities Cost — The following ground rules are the basis for these estimates:

a. No existing facilities usage will be considered;

b. Launch and production rate shall be two/year;

c. Design and manufacturing of the core stage and injection stage, will be accomplished in all new facilities near Michoud. Liquid engines will be designed, developed and manufactured at a separate subcontractor's facility.

5.2.8.6 (Continued)

The costs for the brick and mortar, nonrecurring costs, were established based on the maximum AMLLV vehicle. MLLV facility cost is an itemized percentage reduction based on facilities engineering judgement and inputs from other organizations involved.

The cost dollar figures given for brick and mortar construction, Table 5.2.8.6-I through Table 5.2.8.6-IV include the following phases and resources of project accomplishment.

Accomplishment Phase	Resource
Concepts and Planning	Aerospace Company
Design Criteria	A&E Contractor
Final Design and Specifications	A&E Contractor
Construction	General Construction Contractor
Construction Surveillance	A&E Contractor and Aerospace Company
Contract Administration	Aerospace Company

The cost of these various phases are based on a percentage of construction cost; however, the percentage figure varies from one construction project to another depending on size and complexity. The percentage figures used to arrive at the cost breakdowns were a matter of individual judgement and experience with present day practices.

Construction costs are established based on actual costs of similar construction projects, when available, and concept sketches or individual estimating experience in other cases.

Total maintenance of the brick and mortar, recurring costs, are included in the Tables 5.2.8.6-I through 5.2.8.6-IV and include the following on a per year basis:

a. Craft labor maintenance and material;
b. Transportation and handling;
c. Janitorial service;
d. Coordination;
e. Equipment management;
f. Facilities planning;
g. Equipment and plant engineering support;
h. Facilities management.

The maintenance costs were arrived at by dollars per square foot per year or scaled actuals of similar programs. On this basis, the maintenance costs were scaled down or up, according to facilities engineering judgement, from actual maintenance costs of existing similar Boeing facilities maintenance cost, or actual maintenance cost of NASA sponsored Boeing R&D contract.

Costs shown are for basic steel and concrete structures with utilities and services included. Additional costs for some of the special areas are also shown. These items are listed under "Physical Requirements" following the tables.

5.2.8.6 (Continued)

TABLE 5.2.8.6-I AMLLV AND MLLV MANUFACTURING FACILITIES COST SUMMARY (MAIN STAGE)

	AMLLV		MLLV	
Area	Nonrecurring Brick & Mortar	Recurring $/Year Bldg. Maint.	Nonrecurring Brick & Mortar	Recurring $/Year Bldg. Maint.
Main Stage Mfg. Bldg.	$ 80,985,000	$4,631,000	$ 73,875,000	$4,410,000
Vertical Assembly Building	14,437,000	110,000	11,550,000	110,000
Post Mfg. & Checkout	4,500,000	64,000	3,600,000	64,000
Office	13,406,000	1,095,000	13,406,000	1,095,000
Totals	$113,328,000	$5,938,000	$102,431,000	$5,679,000

Tables 5.2.8.6-II and -III show costs for the manufacturing facility. Table 5.2.8.6-III shows the manufacturing support areas brick and mortar costs (non-recurring) and the building maintenance (recurring) costs. Table 5.2.8.6-III shows the manufacturing building brick and mortar (non-recurring) costs and the maintenance (recurring) costs.

Table 5.2.8.6-IV separates the non-recurring get ready costs for facilities and equipment for the main and injection stages from the totals. The recurring maintenance costs are similarly broken out, so that individual costs can be determined as required for either the main stage or the injection stage.

TABLE 5.2.8.6-II AMLLV AND MLLV MANUFACTURING SUPPORT AREAS (MAIN AND INJECTION STAGE)

Area		Sq. Ft.	$/Sq. Ft. B&M	Total $ B&M	Bldg. Maintenance/ Year $
Vertical Assembly Bldg.	MLLV	79,000	$ 220.00	$15,400,000	$ 165,000
	AMLLV	87,500	$ 220.00	$19,250,000	$ 182,000
Post Mfg. and Stage Test	MLLV	50,000	$120.00	$ 4,800,000	$ 80,000
	AMLLV	50,000	$120.00	$ 6,000,000	$ 100,000
Office	MLLV	650,000	$ 27.50	$17,875,000	$1,460,000
	AMLLV	650,000	$ 27.50	$17,875,000	$1,460,000

5.2.8.6 (Continued)

TABLE 5.2.8.6-III AMLLV AND MLLV MAIN AND INJECTION STAGE MANUFACTURING BUILDING

Area	Sq. Ft.	$/Sq. Ft. B&M	Total $ B&M	Remarks
Bldg. Shell Low Bay	2,700,000	20.00	54,000,000	Includes primary utilities, heat, air conditioning and power.
Bldg. Shell High Bay	250,000	100.00	25,000,000	* 200,000 sq.ft. $20,000,000
Skin and Core Fab.	320,000	15.00	4,800,000	* 250,000 sq.ft. $3,750,000
Rework and Modification	150,000	10.00	1,500,000	* 120,000 sq.ft. $1,200,000
Chemical Clean	67,500	40.00	2,700,000	* 60,000 sq.ft. $2,400,000
Major Clean	22,500	15.00	337,500	* 20,000 sq.ft. $ 300,000
Minor Assembly	500,000	10.00	5,000,000	* 400,000 sq.ft. $4,000,000
Major Assembly	250,000	10.00	2,500,000	* 200,000 sq.ft. $2,000,000
Major Paint	45,000	10.00	450,000	* 35,000 sq.ft. $350,000
Elect./ Electronic	50,000	10.00	500,000	* 40,000 sq.ft. $400,000
Horizontal Instl.	50,000	4.00	200,000	* 40,000 sq.ft. $400,000
Component Test	180,000	25.00	4,500,000	* 150,000 sq.ft. $3,750,000
Subsystem Test	70,000	25.00	1,750,000	* 60,000 sq.ft. $1,500,000
Production Control	100,000	12.00	1,200,000	
Nondestruct Test	25,500	25.00	562,500	*23,225 sq.ft. $404,500
Measurement Control	15,000	30.00	450,000	
Mfg. Dev. Lab	15,000	10.00	150,000	* Floor space and facility dollars for the MLLV are the same except where shown by asterisk.
Equip. Maint.	40,000	1.50	60,000	
Plant Services	40,000	15.00	600,000	
Mock Up	40,000	2.50	100,000	
Receiving and Inspection	60,000	2.00	120,000	
Shipping	37,500	2.00	75,000	
Whse and Stores	500,000	1.50	750,000	Maintenance/Yr.
TOTAL AMLLV			$107,980,000	$ 6,174,000
TOTAL MLLV			$ 98,500,000	$ 5,880,000

5.2.8.6 (Continued)

TABLE 5.2.8.6-IV AMLLV/MLLV MAIN AND INJECTION STAGE MANUFACTURING FACILITY MAINTENANCE COST - RECURRING AND NONRECURRING

	AMLLV Total B&M	AMLLV Total Equipment	MLLV Total B&M	MLLV Total Equipment
	Nonrecurring Costs - Manufacturing Building			
Main Stage	$ 80,980,000	$ 42,342,000	$73,875,000	$40,316,000
Injection Stage	27,000,000	14,114,000	24,625,000	13,439,000
Total	$107,980,000	$ 56,455,000	$98,500,000	$53,755,000
	Nonrecurring Costs - Manufacturing Support Areas			
Main Stage	$ 32,344,000	$ 6,480,000	$28,556,000	$ 6,030,000
Injection Stage	10,781,000	2,160,000	9,519,000	2,010,000
Total	$ 43,125,000	$ 8,640,000	$38,075,000	$ 8,040,000
	Recurring Costs - Manufacturing Building Maintenance			
Main Stage	$ 4,634,000	$ 1,984,000	$ 4,410,000	$ 1,890,000
Injection Stage	1,540,000	662,000	1,470,000	630,000
Total	$ 6,174,000	$ 2,646,000	$ 5,880,000	$ 2,520,000
	Recurring Costs - Manufacturing Support Areas Maintenance			
Main Stage	$ 1,307,000	$ 219,000	$ 1,269,000	$ 208,000
Injection Stage	435,000	74,000	423,000	70,000
Total	$ 1,742,000	$ 293,000	$ 1,692,000	$ 278,000

Main Stage Liquid Engines — The liquid engine building for either the AMLLV or MLLV will contain approximately 850,000 square feet and provide complete facilities for engine fabrication and assembly. Although the liquid engines will be procured items from a subcontractor, facilities and equipment requirements have been estimated. Table 5.2.8.6-V lists nonrecurring facility costs, and recurring maintenance costs. Table 5.2.8.6-VI reflects the facility equipment costs for engine manufacture. These costs will be the same for either the AMLLV or MLLV configuration.

Main Stage Electrical/Electronics — The facilities shown in Table 5.2.8.6-VII identify the floor space and tooling requirements for the Electrical/Electronics systems. 2600 square feet of floor space will be required.

5.2.8.6 (Continued)

TABLE 5.2.8.6-V AMLLV AND MLLV LIQUID ENGINE MANUFACTURING FACILITY

Area	Sq. Ft.	$/Sq. Ft. B&M	Total $ B&M	Maintenance/ Year Bldg.
Fabrication, Assembly	250,000	15.00	3,750,000	
Assembly	150,000	10.00	1,500,000	
Lab	100,000	30.00	3,000,000	
Cleaning	50,000	40.00	2,000,000	
Whse. and Storage	180,000	2.00	360,000	
Support (Aisles, Toilets)	120,000	2.00	240,000	
Building Shell	850,000	20.00	17,000,000	
			$27,850,000	$ 1,795,000

TABLE 5.2.8.6-VI AMLLV AND MLLV LIQUID ENGINE MANUFACTURING EQUIPMENT

Area	Sq. Ft.	Equip. Dollars	$/Sq. Ft. Equip.	Maint./Yr. Equipment-Dollars
Fabrication, Assembly	250,000	$12,500,000	50.00	
Assembly	150,000	2,250,000	15.00	
Lab	100,000	7,000,000	70.00	
Cleaning	50,000	3,500,000	70.00	
Whse. and Storage	180,000	360,000	2.00	
Support (Aisles, Toilets)	120,000		--	
Bldg. Shell	850,000		--	
Total	1,700,000	$25,610,000		$765,000

5.2.8.6 (Continued)

TABLE 5.2.8.6-VII PHYSICAL REQUIREMENTS IN THE ELECTRICAL/ELECTRONIC FABRICATION AREA

- Bench Area
  - Class S Area, 1500 square feet
  - Hand Tools required plus some work holding devices
- Cable Area
  - No control on environment, 200 square feet
  - Hand Tools required
  - Cable layout tables required
  - Kingsley Wire Marker required
- Etched Card Fabrication Area
  - Class S area required, 300 square feet
  - Equipment required:
    - Contact Printer
    - Printing Frame
    - Carbon Arc Lamp
    - Photo Resist Tank
    - Photo Resist Dye Tank
    - Vapor Degrease and Development Tank
    - Etch Tank (Ceramic)
    - Rinse Tanks
    - Drying Equipment
      - Infra Red Heat
      - Warm Air Fan
    - Spray Gun
- Conformal Coating Area
  - Class S environment, 300 square feet
  - Equipment required:
    - Oven
    - Table
- Potting Area
  - Class S environment, 300 square feet
  - Tools:
    - Hand Tools
    - Potting Molds (50 Total)
    - Rack for Molds

5.2.8.6 (Continued)

Test Facility Requirements — Test facility requirements are as follows:

a. Floor space requirements - 160- by 100-foot area or 16,000 square feet;

b. Environmental conditions - air conditioned facility with conditions similar to existing lab facilities. ($70 \pm 18^{\circ}F$ and 60 percent relative humidity);

c. Lighting - minimum of 100 foot-candles at working surfaces;

d. Test cells - test cells will be constructed of concrete block or concrete slab to withstand the force of complete failure of the largest component tested within the cell. Possible consideration should be given to blow-out panels in the roof or ceiling;

e. Nitrogen system:

   1. Nitrogen @ 5000 psig all test stations,

   2. Nitrogen @ 3000 scfm for one minute and 3500 psig at the GN_2 test cells,

   3. Super dried (2 PPM moisture content) 125 psig purge nitrogen @ $130^{\circ}F$ at each test station;

f. General construction - walls and ceilings should be finished in a hard surface material of epoxy type paint to provide resistance to clipping, flaking or powdering. Floors should be covered with a dust resistant vinyl floor material;

g. Special considerations - the test facility should be located at an outside wall for the location of the large component test cells. The immediate outside area could be fenced off and used as the flow exhaust area and provide for vent control systems in the event of having to test fluid contaminated hardware.

Engine Test Facility — Ten pit areas with hydraulic lift, intake and exhaust blowers, work platforms, electrical outlets, lighting, facility drain system (area of 10,000 square feet is required).

Test stations required in the electrical/electronic test area are:

a. Signal Conditioner Test Station;
b. Vibration Test Station;
c. RF Test Station;
d. Telemetric RF Test Station;
e. PCM/FM Test Station;
f. Pressure Transducer Test Station;
g. On Board Computer Test Station;

5.2.8.6 (Continued)

h. Antenna Test Station;
i. Instrumentation Test Station;
j. Acoustic Test Station.

5.3 INJECTION STAGE MANUFACTURING PLAN

This manufacturing plan presents manufacturing, fabrication, and assembly methods for the injection stage of the Advanced Multipurpose Large Launch Vehicle (AMLLV) and the half size Multipurpose Large Launch Vehicle (MLLV). As the injection stage is essentially identical for both the AMLLV and MLLV, only one plan has been prepared to cover both injection stages. Where the AMLLV injection stage differs from the MLLV, the differences are shown in brackets for the AMLLV. Brackets will also be used to enclose material relating to the AMLLV when it is important to display such information simultaneously with the MLLV.

The plan is, where practicable, an extrapolation of fabrication techniques developed for the Saturn V, S-IC booster stage. By making use of the plans, processes and tooling concepts developed for that stage, program cost for the fabrication of the MLLV [AMLLV] injection stage will be minimized. Nevertheless, where different processes appear advantageous, they are incorporated in the plan.

5.3.1 Injection Stage Description

The injection stage will consists of propulsion modules stacked atop each other. The stage may contain as many as three modules, depending on mission requirements. The engine module will be a cylindrical, aluminum skin-stringer-frame structure, 56.7 [71.7] feet in diameter by 15 [18.3] feet in height. The fuel modules will be 8.7 feet height. Each module will contain two toroidal tanks. The bottom module of the stage will contain the rocket engines. Two engines per module will be used.

The cylindrical skin structure of each module, which is similar to the forward skirt of the core stage vehicle, will be constructed from 7075-T6 aluminum skin panel subassemblies. The torus tanks will be constructed from 2219-T87 aluminum. The outer, LH_2 tank will be attached to the inside wall of the cylindrical skin structure. The inner LOX tank, located within the inner circumference of the LH_2 tank, will be attached to the outer tank by means of a fiberglass/epoxy skirt. Engines will be attached to thrust posts (only on bottom module) mounted circumferentially around the injection stage skin. The module for the bottom portion of the injection stage is illustrated in Figure 5.3.1.0-1. Other modules will be similar but do not contain the rocket engines and accessories.

5.3.2 Guidelines and Assumptions

This manufacturing plan was based on the injection stage design configuration illustrated in Boeing documented cost studies of Multipurpose Large Launch Vehicles. These studies are contained in Volume II of this final report, Half Size (MLLV) Conceptual Design; and D5-13421-2, Study of Advanced Multipurpose Large Launch Vehicles - Technical Report.

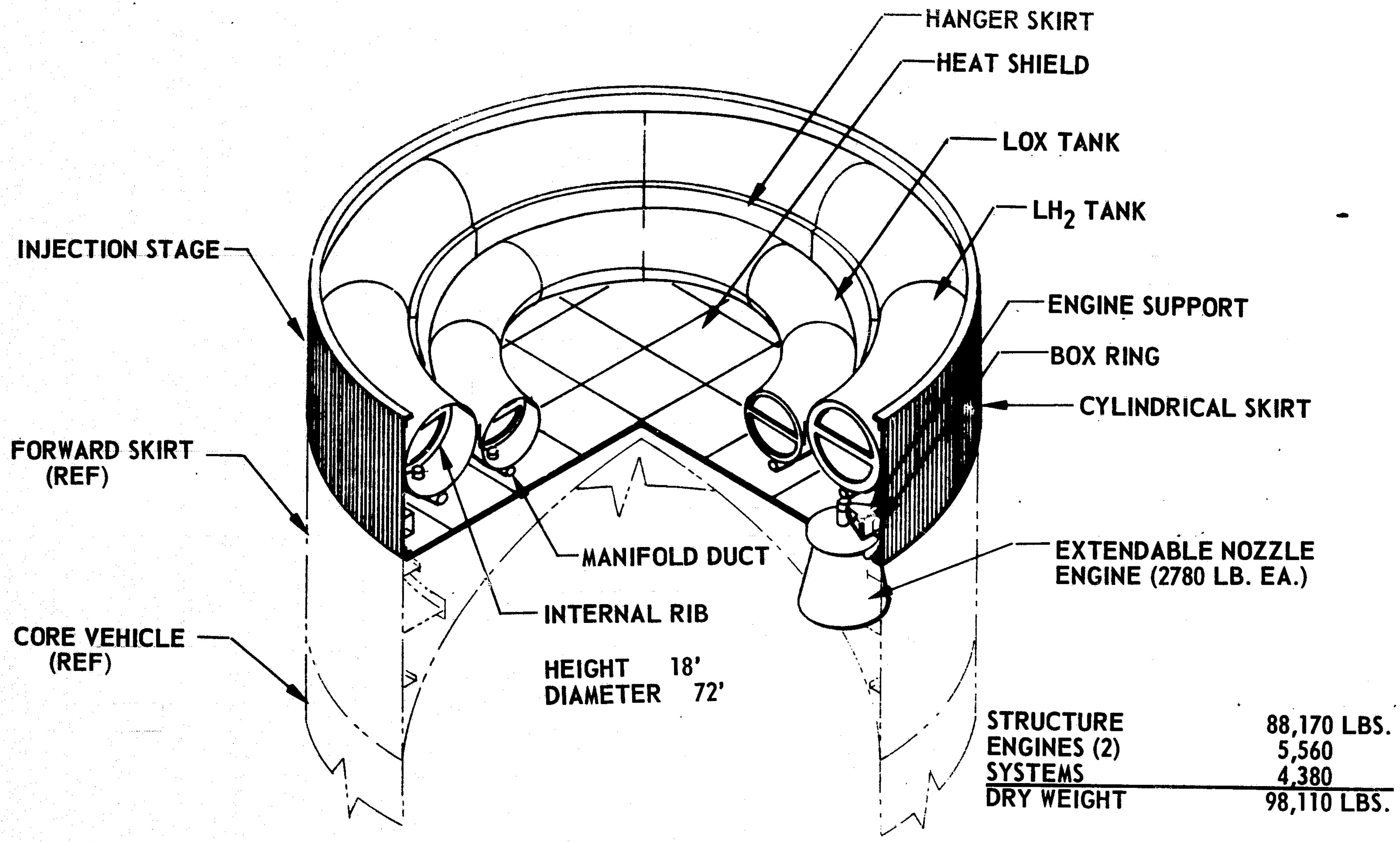


FIGURE 5.3.1.0-1 INJECTION STAGE - AMLLV

5.3.2 (Continued)

The injection stage manufacturing plan was developed in accordance with the following guidelines and assumptions:

a. A production rate of two vehicles per year;

b. Saturn V, S-IC plans, processes and tooling will be used for producing MLLV [AMLLV] hardware wherever possible;

c. All tasks are planned on the basis of two-shift; forty-hour work week;

d. The plan is based on LOX cleaning for which techniques and processes have previously been developed;

e. All subsystems functional and acceptance testing will be performed by the vendor except as noted;

f. No provisions have been made for spares or test hardware;

g. Make-or-buy determinations will be in consonance with precedents established by the Saturn program.

5.3.3 Injection Stage Fabrication and Assembly Procedures

The lower injection stage module (the engine module) will be manufactured in the following major components:

a. Torus tanks, comprised of LH_2 tank and LOX tank;
b. Skin panel assemblies;
c. Interface ring;
d. Thrust ring frame;
e. Hanger skirt;
f. Engine mounting forgings;
g. Base heat shield assemblies;
h. Engine and accessories.

The fabrication and assembly sequences required to produce the major structural assemblies are described below. Other assemblies such as engine and accessories are not discussed, other than final installation.

5.3.3.1 LH_2 Torus Tank Fabrication and Assembly Procedures

The LH_2 torus tank is approximately 56 [71] feet in diameter and has a cross-section diameter of 8 [10] feet. The fabrication plan calls for manufacturing this tank in the following major subassemblies or parts:

a. LH_2 manifold ring (2219-T87 AL);
b. LH_2 manifold fittings (2219-T87 AL);
c. LH_2 tank outer T-ring (2219-T87 AL);

5.3.3.1 (Continued)

d. LH_2 tank inner T-ring (2219-T87 AL);
e. LH_2 tank section splice-segments (2219-T87 AL);
f. LH_2 tank shear-webs (2219-T87 AL):
g. LH_2 tank skins (2219-T87 AL).

As the LH_2 and LOX torus tank of the injection stage are similar in configuration and structure (differing only in size), the manufacturing sequences required to produce these tanks will be almost identical. In describing these sequences, the LH_2 tank is taken as the typical example. The LOX tank assembly sequence is presented as a matter of format and its context will be referenced to the LH_2 tank assembly where fabrication plans are the same.

The following paragraphs describe the detail fabrication and final assembly operations for each of the above assemblies.

LH_2 Manifold Ring — The LH_2 manifold ring will be constructed in 12 tubular segments. The tube will be purchased in predetermined lengths and stretch-formed to circular curvature. The segment will then be heat treated to the designated temper. After heat treat, the part will be cleaned and the ends trimmed. The ring segments will then be transferred to a Niles boring mill where the upper and lower fitting openings will be machined. Next, the ring segment will be moved to the LH_2 manifold segment weld fixture, Figure 5.3.3.1-1, and positioned. The lower manifold fittings (previously fabricated) will then be welded to the ring segments. The ring segments will then be transferred to the LH_2 manifold ring assembly fixture, Figure 5.3.3.1-1. The ring segments will then be positioned in the fixture with the lower fittings on the underside. The ring segments will be aligned, clamped, and welded, and the welds will be X-rayed and repaired as required. The upper manifold fittings will subsequently be positioned on the upper opening, aligned, clamped, and welded in position. A holding fixture (similar to lower manifold fitting hold fixture) will be used to hold fittings for welding. The now complete LH_2 manifold ring will be removed from its assembly fixture and transferred to the LH_2 tank assembly fixture, Figure 5.3.3.1-2.

Upper and Lower LH_2 Manifold Fittings — The LH_2 manifold fittings will be fabricated from cylindrical aluminum tubing. The tube will be cut to length, rough machined and heat treated to designated temper. The part will then be cleaned, finish machined, and transferred to a holding area while awaiting assembly into the LH_2 manifold ring segment or ring frame.

LH_2 Outer T-Ring — The outer T-ring is the circumferential splice between the upper and lower half tank skins. It will also be fabricated in 12 segments. The segments will be aluminum extruded T-sections. The segments will be roll-formed to circular contour, heat treated, ends trimmed then welded into the ring form. This ring is then X-rayed and repaired as required.

Figure 5.3.3.1-3 depicts this ring in the welding fixture. After the ring has been trimmed and inspected, it will then be transferred to the LH_2 tank assembly fixture, Figure 5.3.3.1-2, using the T-ring handling tool depicted in Figures 5.3.3.1-4 and 5.3.3.1-5.

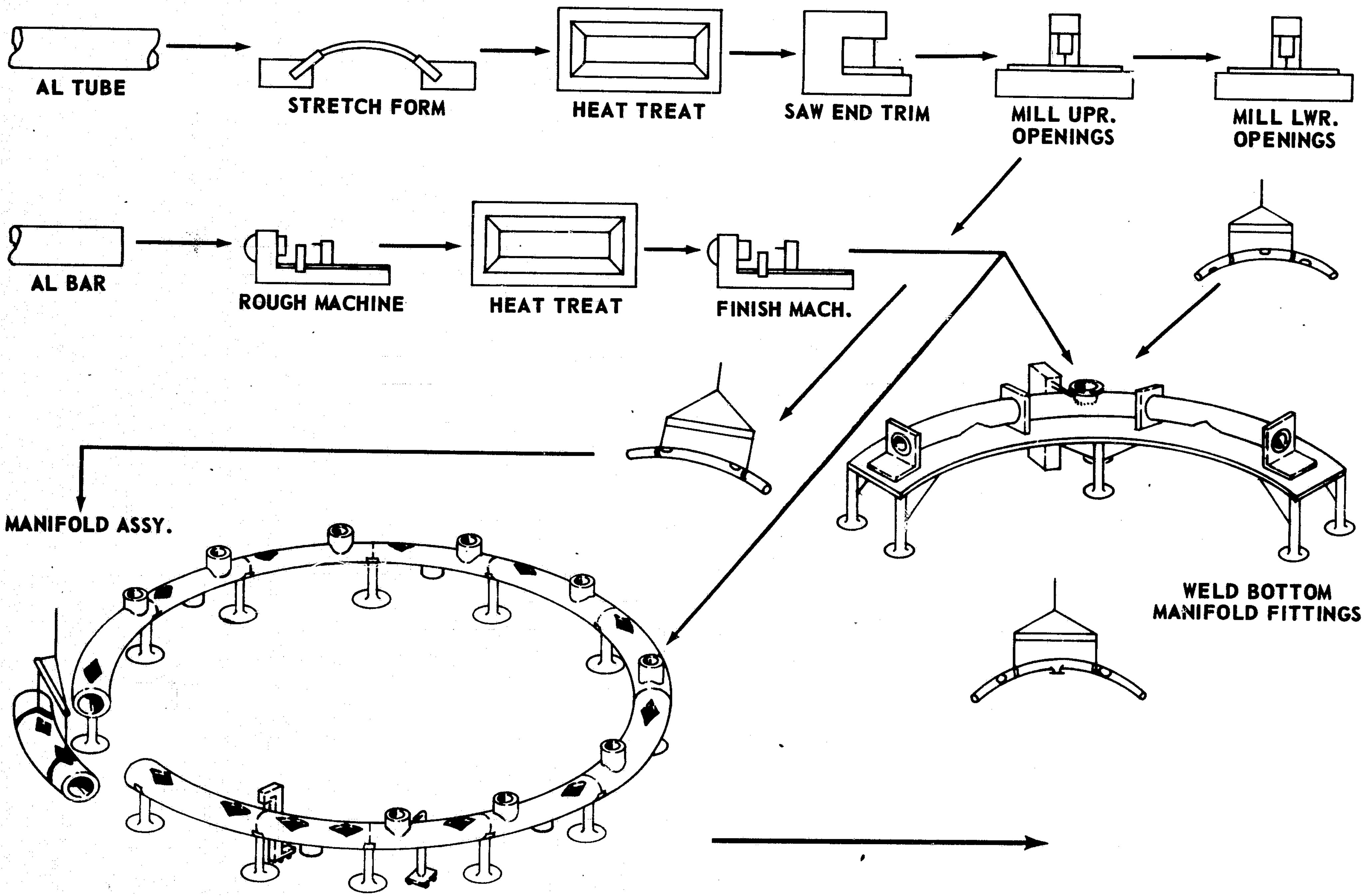


FIGURE 5.3.3.1-1 LH_2 MANIFOLD RING ASSEMBLY SEQUENCE

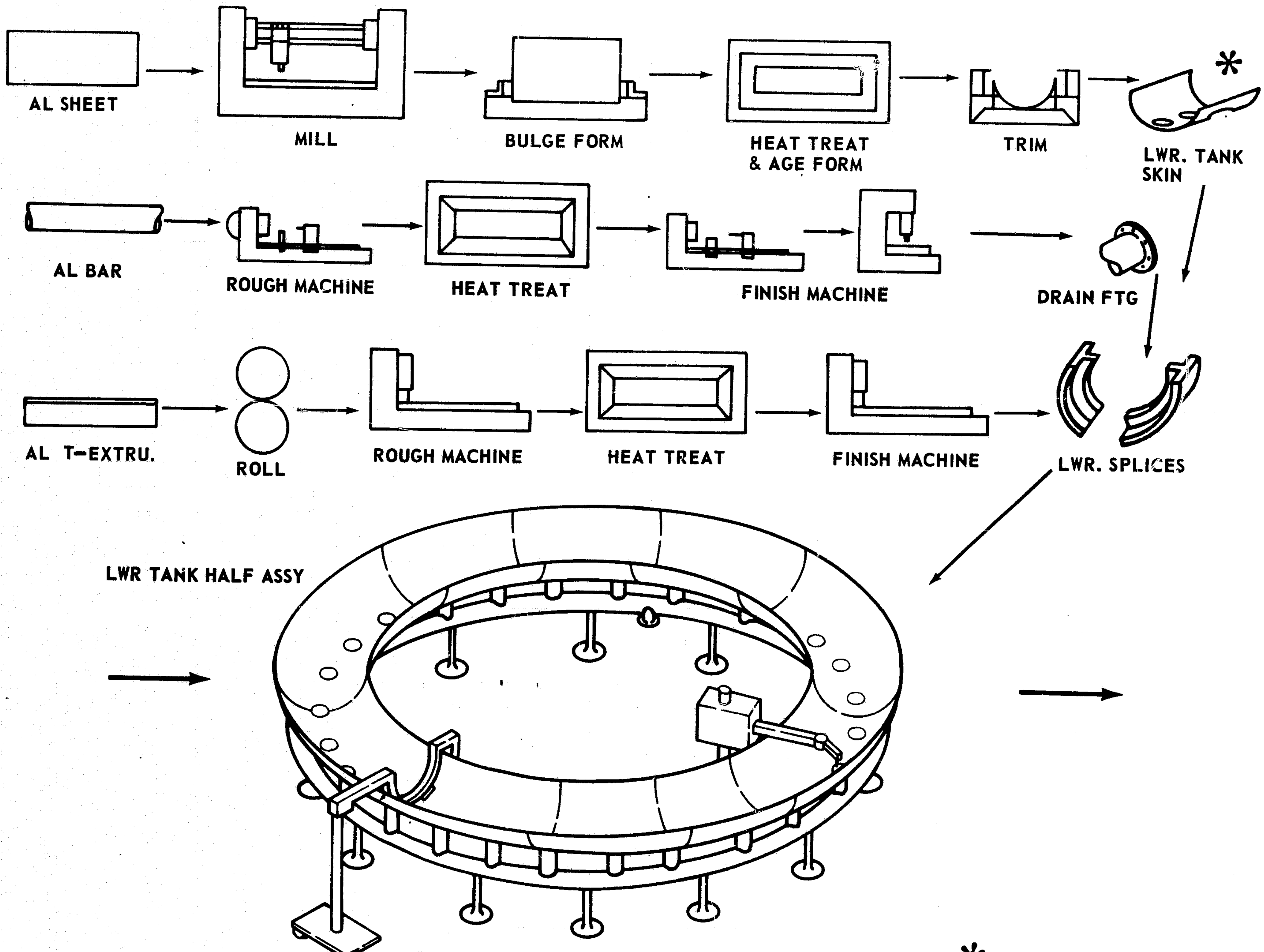


FIGURE 5.3.3.1-2 LH_2 TANK ASSEMBLY FIXTURE

*MAT'L SIZE IMPACT ITEM

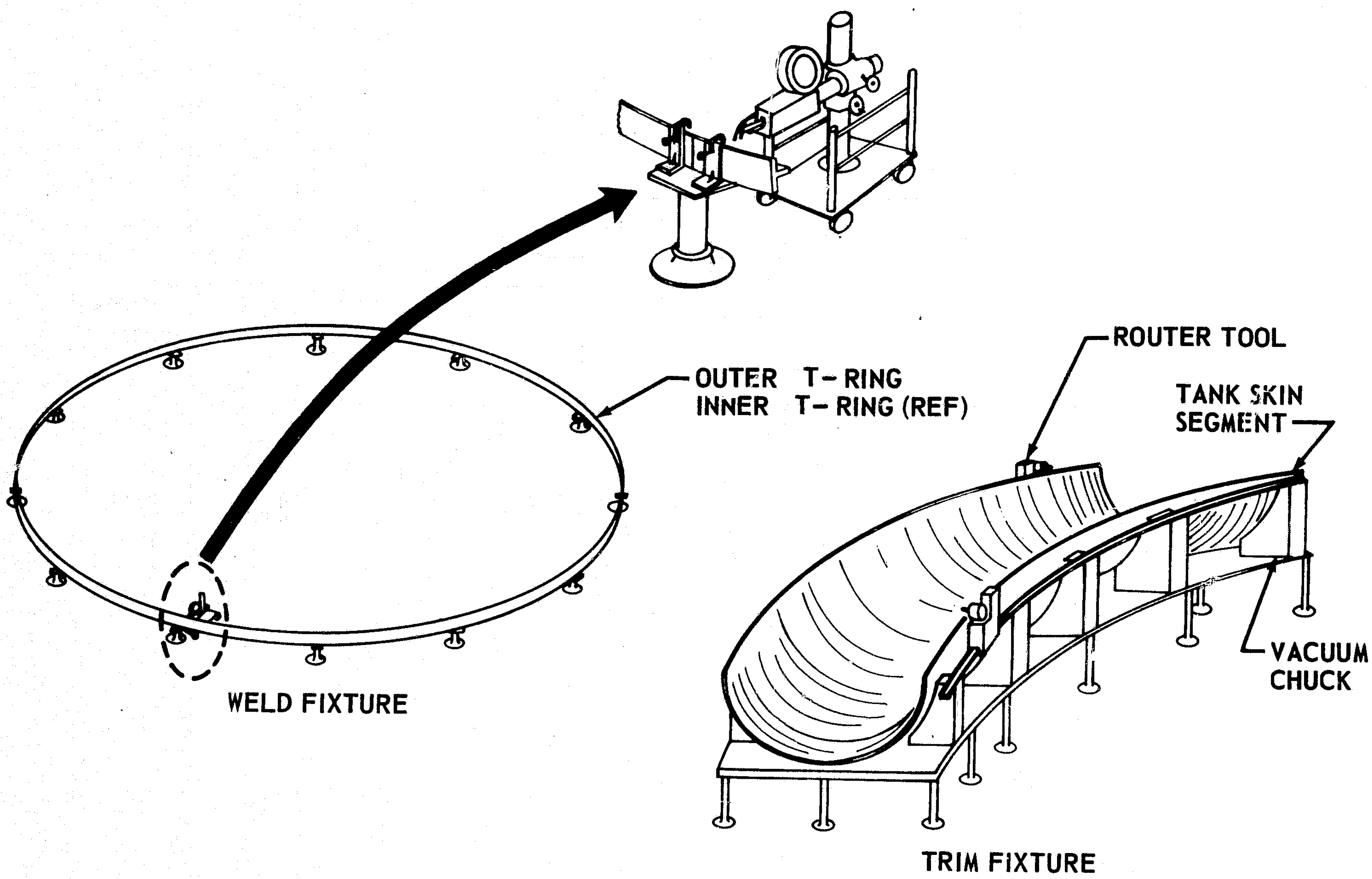


FIGURE 5.3.3.1-3 T- RING WELD FIXTURE AND TANK SKIN TRIM FIXTURE

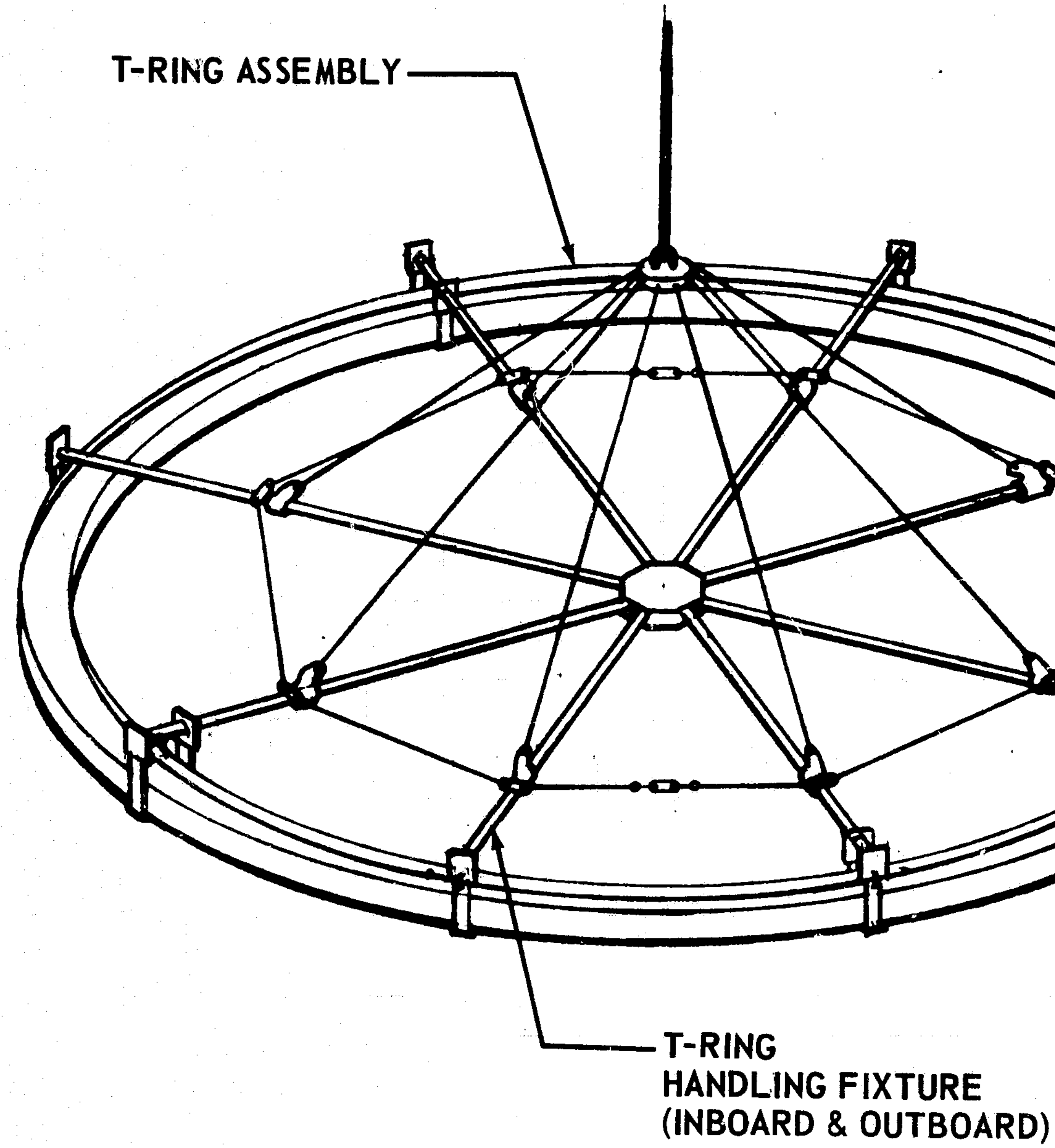


FIGURE 5.3.3.1-4 T-RING HANDLING TOOL

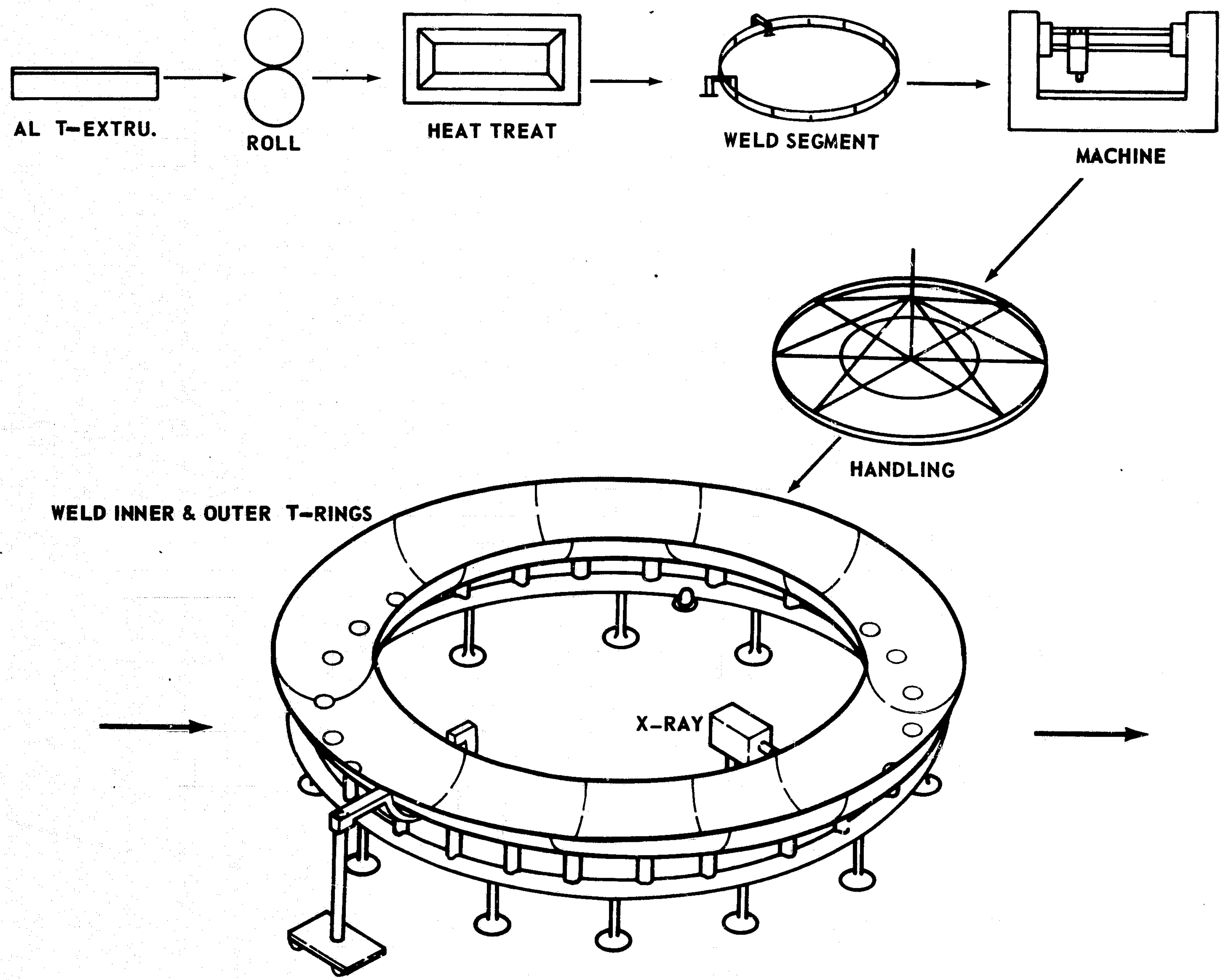


FIGURE 5.3.3.1-5 T-RING ASSEMBLY

5.3.3.1 (Continued)

LH$_2$ T-Ring — The inner T-ring will be fabricated in the same manner as the outer T-ring. It will also be constructed from extruded, aluminum T-sections. From its assembly station, the inner T-ring assembly will be transferred to the LH$_2$ tank assembly fixture.

LH$_2$ Section Segments — The section splice segment is one quadrant of the cross-section splice ring that will interface with the LH$_2$ tank skins ends. Four segments will be required at each tank skin joining end. The section splices will be fabricated from 2219-T87 aluminum T-extrusions. The extrusions will be rolled to contour, heat treated, then finish machined. The complete splice sections will then be transported to the LH$_2$ tank assembly fixture, Figure 5.3.3.1-6.

LH$_2$ Shear Webs — The shear web assembly for the LH$_2$ torus tank will be used to provide internal structural stiffening and maintain the circular cross-section shape. Twelve shear web assemblies will be used. Each assembly will be fabricated in two parts, consisting of an upper and lower half. The lower section will have a U-shaped opening where the upper half will not. Except for this detail, the fabrication of the two halves will be similar. Assembly sequences are illustrated in Figure 5.3.3.1-7.

LH$_2$ Tank Skins — The LH$_2$ tank skins will be fabricated from 12 torus segments. The segments, constructed from 2219-T87 aluminum, will consist of an upper and lower half. The section halves will be formed by the bulge form method. Figures 5.3.3.1-2 and 5.3.3.1-6 illustrate the manufacturing flow of these parts.

Other alternatives considered for the fabrication of the LH$_2$ torus tanks are bulge forming the tank segments in the inner/outer half configuration and explosive forming the tank segments from cylindrical tubes. The first alternative would involve an additional bulge form die, but would be advantageous in that the weld seam would be placed at the area of least stress. The fabrication method selected for this manufacturing plan places the weld seam at the area of the highest stress, but involves making only one bulge form die.

The second alternative, explosive forming the segments from cylindrical tubing, is feasible at this time. Tubing of the size required is now available from industry and studies being conducted at the present time indicate that this fabrication method would be desirable.

LH$_2$ Major Assembly — The assembly of the LH$_2$ tank will begin by the fabrication of the LH$_2$ manifold ring. Once this ring is complete, it will be placed in the LH$_2$ tank major assembly fixture, Figure 5.3.3.1-2. Here, 12 lower half tanks and 12 splice sections will be placed in the fixture and welded. This operation will be followed by placing the T-rings on the lower tank halves and welding. The upper tank skins and shear webs will then be installed; the tank skins being welded to the T-chords and the shear webs being mechanically fastened to the splice stations, Figures 5.3.3.1-6 and 5.3.3.1-8.

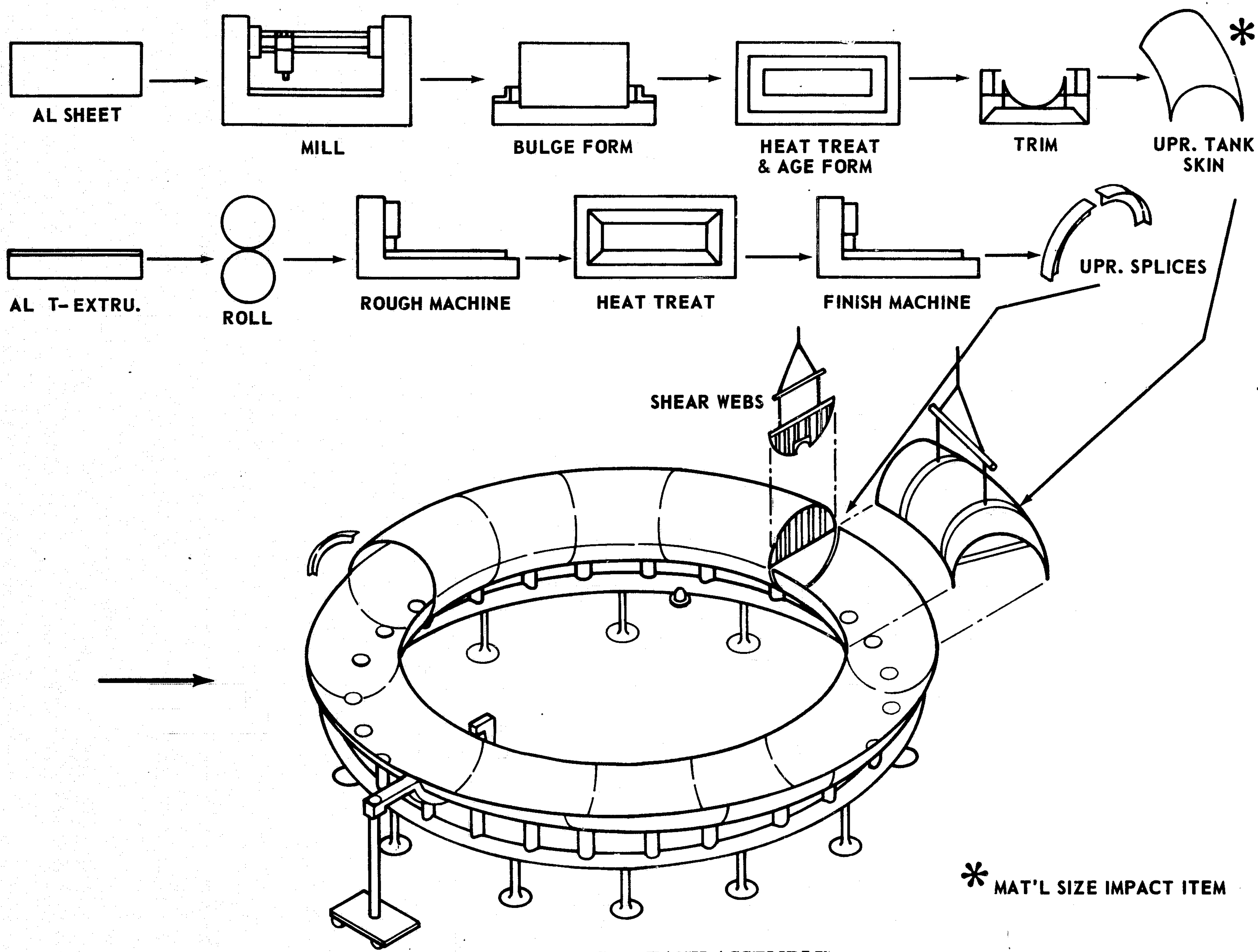


FIGURE 5.3.3.1-6 LH_2 TANK ASSEMBLY

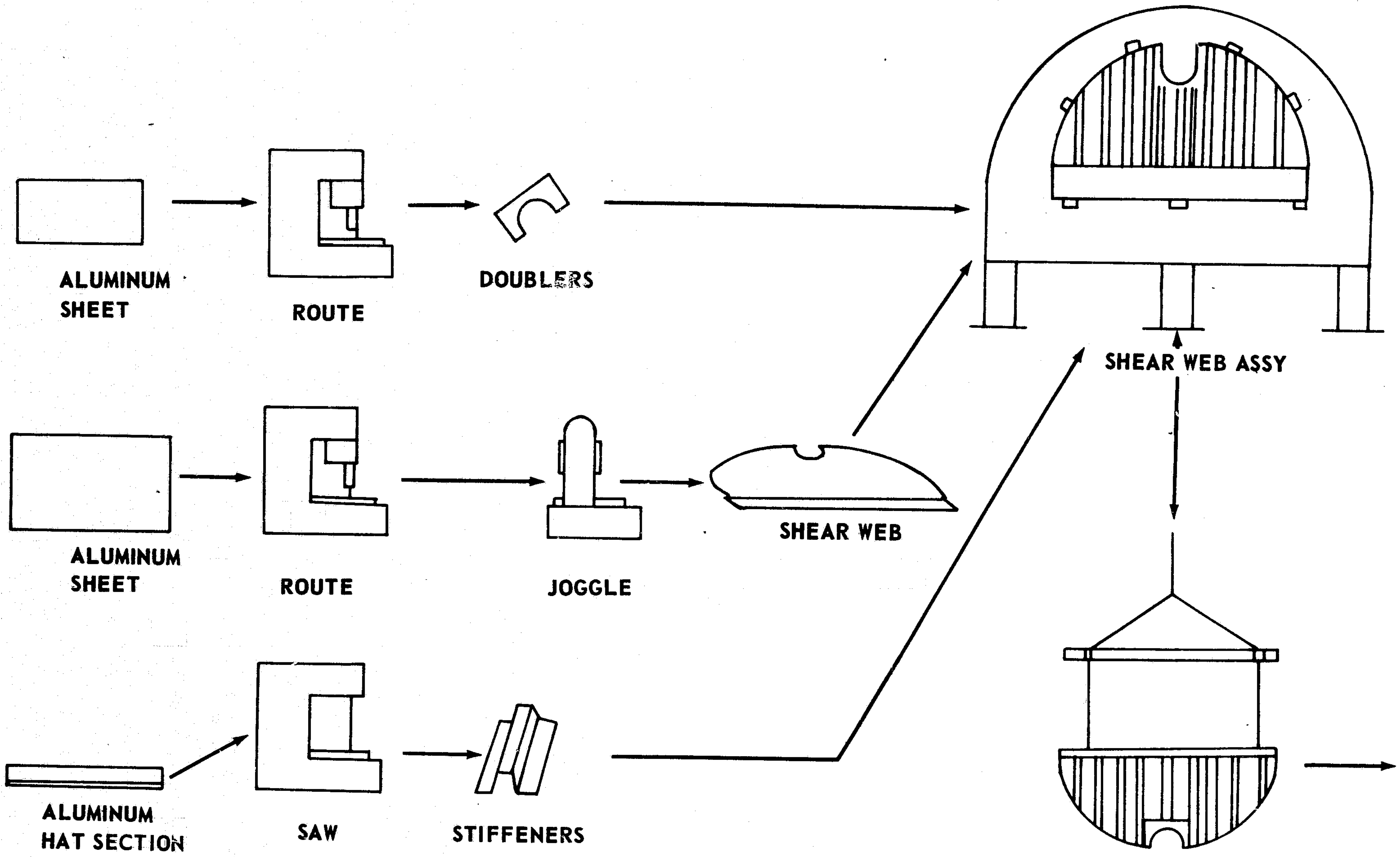


FIGURE 5.3.3.1-7 SHEAR WEB ASSEMBLY

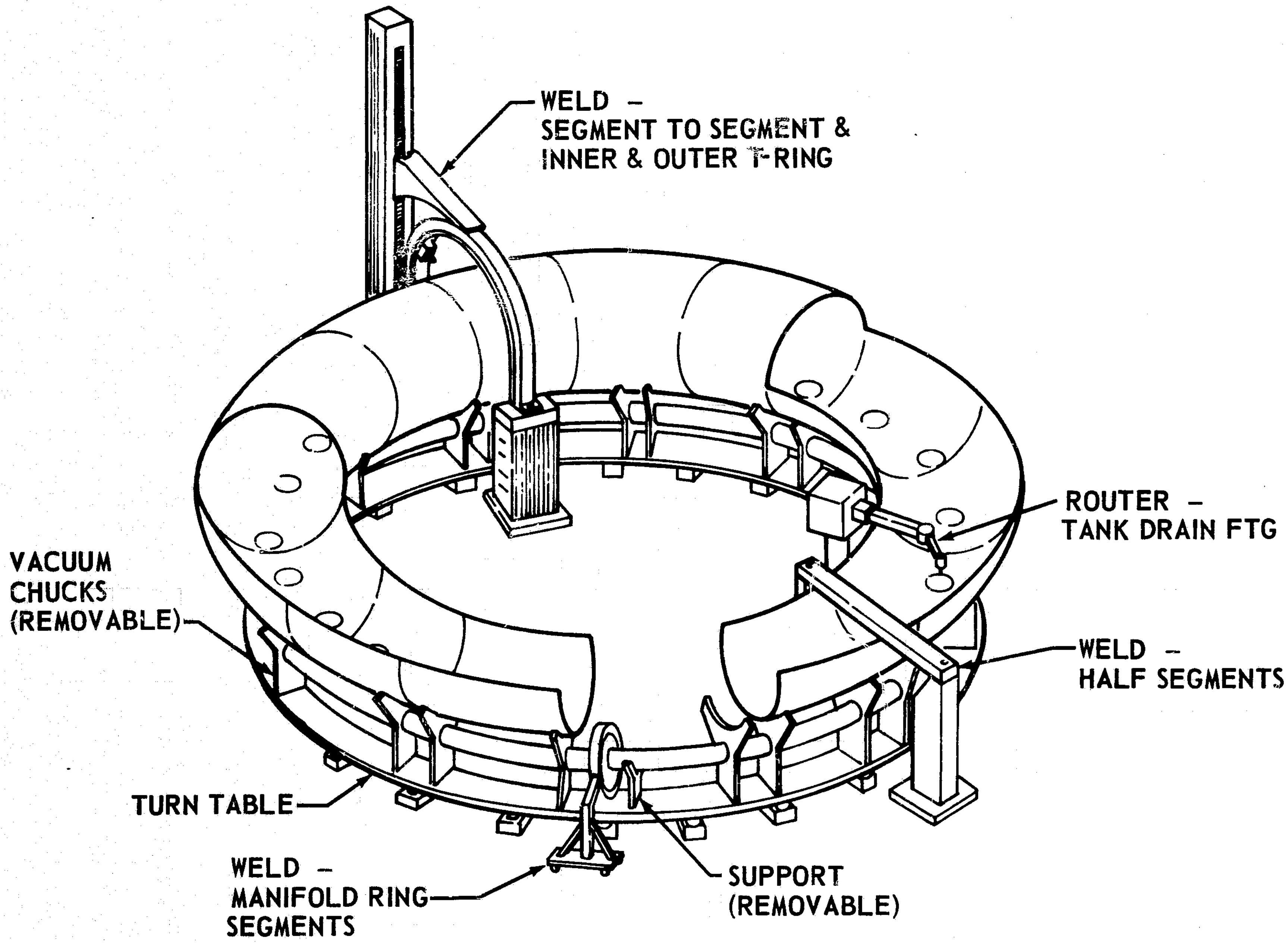


FIGURE 5.3.3.1-8 LH_2 TANK ASSEMBLY

5.3.3.1 (Continued)

The completed tank will then be transferred to the hydrostatic test facility where the assembly is LOX cleaned and proof tested. The tank is then returned to the assembly fixture where the fiberglass hanger skirt (with LOX tank attach holes previously drilled) is installed. The LH_2 tank will then be moved to the final injection stage assembly fixture.

5.3.3.2 LOX Torus Tank Fabrication and Assembly Procedures

The LOX tank is similar in configuration to the LH_2 tank. It will be approximately 40 [50] feet in major diameter and will have a cross-section diameter of 5.75 [6.5] feet.

The LOX tank will be constructed from the following subassemblies:

a. LOX manifold ring;
b. LOX manifold fittings;
c. LOX tank outer T-ring;
d. LOX tank inner T-ring;
e. LOX tank section splice segments;
f. LOX tank skins;
g. LOX tank shear web.

The assembly and fabrication methods for each of these components is very similar to the methods proposed for manufacturing the corresponding part of the LH_2 torus. The materials of construction of the LOX tanks are the same as the LH_2 tanks.

<u>LOX Manifold Ring</u> — Fabrication sequence will be the same as that for the LH_2 manifold ring;

<u>LOX Manifold Fittings</u> — Fabrication sequence will be the same as that for the LH_2 manifold fittings;

<u>Outer T-Ring (LOX Tank)</u> — Fabrication sequence will be the same as that used for the LH_2 outer T-ring assembly;

<u>Inner T-Ring (LOX Tank)</u> — Fabrication sequence will be the same as that used for the LH_2 inner T-ring assembly;

<u>Section Splice Segments (LOX Tank)</u> — Fabrication sequence will be the same as that used for the LH_2 section splice segments;

<u>Shear Webs (LOX Tank)</u> — Fabrication sequences will be the same as that used for the LH_2 shear web assembly;

<u>LOX Tank Skins</u> — Fabrication sequences will be the same as that used for the LH_2 tank skins;

5.3.3.2 (Continued)

LOX Tank Major Assembly — The major assembly sequence will be the same as that for the LH_2 torus tank final assembly.

Upon completion of the assembly, the LOX tank will be transferred to the Hydrostatic Test Facility where it is LOX cleaned and proof tested. The tank will then be transferred to the final injection stage assembly fixture, where the fiberglass hanger skirt is preinstalled.

5.3.3.3 Skin Panel Assemblies

The injection stage outer skin will be composed of 12 skin panel subassemblies. Each skin panel assembly will consist of a milled and roll-formed 7075-T6 aluminum alloy skin to which 23 hat section stiffeners will be mechanically fastened.

The skin panel assembly itself will be made up of detail parts and no subassembly will be required in its fabrication. Fabrication of these parts and final assembly is described below.

Skin Panel - Skin Segments — The skin panels will be cut from 7075-T6 aluminum alloy sheet stock, milled to the proper thickness and rolled to contour. When all machining and forming operations are complete the skin will be cleaned, primed and stored for later use.

Skin Panel - Hat Section Stiffeners — Each of the 23 hat section stiffeners will be fabricated from a 7075-T6 aluminum extrusion. An upset will be joggled in the middle of the long stringer and at both ends to accommodate the interface rings. When forming is complete, the stringers will be cleaned, primed and stored for later use.

Skin Panel Final Assembly — The skins and preformed hat sections will be loaded into a subassembly jig. A drill plate will be positioned over the stringers and fastener holes will be drilled with automatic airfeed drills. The parts will be removed from the jig, cleaned, deburred, and reinstalled in the subassembly jig. All fasteners except those common to ring segments and thrust ring frame will be installed. Those holes will be pilot drilled for later assembly in the major assembly jig. A 24th hat section will also be installed at the splice station at final assembly. When subassembly is complete, the skin panels will be placed on a transportation/storage dolly for future use.

5.3.3.4 Thrust Ring Segments

Two thrust rings, each consisting of 12 segments, will be used in the basic injection stage. These rings will be mechanically fastened to the skin at locations above and below the engine mount forgings.

Each segment will consist of a honeycomb core to which upper and lower face sheets and Z-strips are bonded. Inner and outer T-chords will be mechanically fastened to

5.3.3.4 (Continued)

form the completed segment. The inner and outer T-chords, Z-strip, and upper and lower face sheets will be cut to size and rolled to the proper curvature as required. A track router will be used to trim the face sheets. All face sheets, T-chords, and Z-strips will be deburred, alkaline cleaned, rinsed, recleaned in a hot deoxidizing solution, rerinsed and then dried. Rough formed honeycomb cores will also be placed in a track router. A combination vacuum/polyglycol chuck will be used to hold the structure firm while excess material is removed.

When all cutting and routing operations are complete, the hardened polyglycol will be rinsed away with hot water. Completed honeycomb sections will be once again degreased and dried. Adhesive primer will then be applied to these surfaces which receive bonding agent.

Final assembly of the thrust ring segment will be accomplished in the ring segment assembly fixture. A hoisting sling will be used to load Z-sections into the ring segment bonding fixture. Face sheets will be coated with adhesive bonding agent and loaded into the fixture. A vacuum bag will be placed over the face sheets to provide the force necessary to assure a permanent bond. The entire assembly will then be moved to the autoclave where the curing cycle will be completed. When the prescribed curing time has expired, the assembly will be removed and allowed to cool. The honeycomb web will then be conversion coated and spray primed. The inner and outer T-chords will be loaded into the ring segment assembly fixture. The honeycomb web will be positioned also and all attach holes will be drilled with the use of drill plates and automatic air feed drills.

When the attach holes are completed, parts will be removed, deburred and replaced in the fixture. All fasteners will be installed which are common to the T-chords and web assembly only. Rivets will be touched up with primer prior to removal to a transport/storage dolly.

5.3.3.5 Interface Ring Segment Assembly

The interface ring is the splice between modules. The ring segments are extruded 2219-T87 aluminum sections stretch-formed to contour.

Two interface rings will be required for each injection stage module. The interface ring assembly is fabricated in 12 segments. The segments are purchased in extruded sections and stretch-formed to circular curvature. The ring segments are heat treated to the designated temper and the ends of the ring segments are trimmed. The completed ring segment will have a protective finish applied prior to transporting to the final assembly fixture for the injection stage. The ring segments are assembled into the interface ring assembly at this location.

5.3.3.6 Hanger Skirt

The hanger skirt is composed of 12 fiberglass/epoxy 30-degree arcs, which form a complete cylinder. The upper periphery of this cylinder attaches to the inside diameter of the LH_2 toroidal tank while the lower edge is fastened to the outside diameter

5.3.3.6 (Continued)

of the LOX toroidal tank. Fastening to the tank is made with bolts passing through spherical bearings in the skirt.

Each fiberglass/epoxy segment will be laid-up on a curved form. The skirt will be thicker at each edge where attachment will be made. Reinforcing metal strips will be sandwiched between fiberglass layers. When the laminate is cured, the segment will be removed from the form and placed on a trim fixture. A track router will trim the edges, and drill plates which are located on this same fixture will be used to drill holes to accommodate spherical bearings. These holes will then be reamed and bearings pressed into place. The rings will then be placed into a holding fixture and fastened together at their centers using small doublers on each side of the skirt.

5.3.3.7 Engine Mount Structure

The engine mounting structure of the injection stage will be an aluminum (7075-T6) forging. The structure will be of a tapered cantilever configuration with circular holes in the web. The rough aluminum forgings will be machined to the net configuration, then the attach holes for the engine and mounting locations will be drilled. The completed engine mounting will then be finish-protected and transported to the final injection stage assembly fixture.

Major assembly operations will consist of NC-milling the rough forging to net size, cleaning and applying a protective finish. The forging will then be transported to the final assembly station.

5.3.3.8 Base Heat Shield Assembly

The base heat shield will be composed of aluminum honeycomb bonded to two aluminum face sheets. The aft face sheet will have Refrasil support studs attached. The substructure for supporting the panels inside the lower thrust ring will be a grid structure consisting of 7075-T6 aluminum alloy extruded channels, I-beams, and clip angles. The outer portion of this structure will be attached to the underside of the lower thrust ring frame. Components are constructed as described below.

Base Heat-Shield Support Structure — The base heat-shield support structure will be constructed by locating in the assembly fixture the extruded 7075-T6 aluminum channels, I-beams, and clip angles which have been cut net from the purchased raw material, cleaned, conversion coated and primed. All holes common to these parts will be drilled, the parts unloaded, deburred, replaced and mechanically fastened. Those beams which extend beyond the inner diameter of the thrust ring frame will not fasten at this point but will be drilled and deburred for fastening at stage final assembly.

Honeycomb/Refrasil Panels — Aluminum face sheets will be sheared to rough size. They will then be deburred, alkaline cleaned, rinsed, cleaned in a hot deoxidizing solution, rinsed and dried. Surfaces to be bonded will be sprayed with an alkaline primer. The adhesive film will be applied to these surfaces just prior to bonding.

5.3.3.8 (Continued)

Honeycomb cores which are purchased to rough size will be degreased and dried. The face sheets and honeycomb will be sandwiched and vacuum bagged to apply even pressure to the face sheets. The entire assembly will be moved into an autoclave for the curing cycle. When pressure is reached on the outer surface of the assembly, the vacuum side will be vented to the atmosphere. When the adhesive has cured, the fixture will be removed and cooled. Using a drill jig, holes will be drilled through the cores and Refrasil attach stud inserts will be pushed into these holes for fastening rigidity. The part will now be located by these inserts onto a router table and the edges will be trimmed net. The finished panels will then be conversion coated and primed. The Refrasil attach bolts will be mechanically attached to the honeycomb core at heat shield assembly. They will be held to the core by studs attached to the aft face sheet of the honeycomb panel. Buttons will hold the bolt onto the studs.

Heat Shield Major Assembly — Major assembly of the heat shield will be accomplished by first moving the support frame, which has been assembled in the inverted position, to the assembly station. A handling tool for this purpose will be used. Here the honeycomb panels will be positioned on the frame and drill templates which are indexed to the assembly fixture are used to drill the attach hole pattern. The parts will then be removed. The honeycomb core holes will be enlarged, deburred and fitted with attach inserts which are potted into place. The support frame holes will be deburred; the honeycomb cores will be replaced and mechanically fastened. Next the Refrasil attach bolts will be cut to size and edges sealed. They will be placed into position with the studs penetrating them. Buttons will be attached to the studs to hold the Refrasil in place. The Refrasil edges will overlap to improve insulation.

It should be noted that the heat shield will be finished at stage assembly. The honeycomb installed thus far, will not reach to the edge of the frame and the Refrasil will not reach the edge of the honeycomb. This will permit overlapping in final assembly. The bulk of the installation will be accomplished at this point to reduce the amount of upside-down work at assembly.

Upon completion of the assembly, it will be inverted (using a tool for that purpose) and moved to the stage final assembly position.

5.3.3.9 Engine Assembly

The injection stage can vary from one to three modules. The number of modules used will depend upon the mission requirements. With the single module configuration, two engines are used. For the AMLLV configurations, two 250,000-pound thrust engines are used. For the MLLV configurations, two 125,000-pound thrust engines are used. In both the AMLLV and MLLV configurations, the engines are mounted 180 degrees apart on the engine mounting structure. When additional modules are added to the injection stages two additional engines are added per injection stage module.

The engines are received as an assembled subsystem from the propulsion contractor. The stage contractor will mount the engines on the stage and ship the assembly to the

5.3.3.9 (Continued)

launch site for static testing prior to assembly into the vehicle configuration. A description of the engine is not included herein, as many of its parameters are classified confidential.

5.3.3.10 Injection Stage Final Assembly

Following are the final assembly sequences for the injection stage. Detail part-flow sequences are illustrated on Figure 5.3.3.10-I.

Lower Module — The injection stage may consist of from one to three modules; the lower module will contain all of the engines and heat shield.

Ring Frame Assembly — Fabrication of the injection stage will begin by placing the aft interface ring frame segments into position on the injection stage final assembly fixture using the ring frame segment handling fixture. Fastener holes will be drilled, deburred, and fasteners are installed to complete the ring. Segments of the lower honeycomb thrust ring, located at the bottom of the thrust posts, are positioned in the fixture, drilled, deburred, and mechanically fastened together using forged back-up fittings as stiffened splice plates. The forged thrust posts located at each engine position will then be installed with a handling fixture, and mechanically fastened to the lower ring. Segments of the upper honeycomb thrust ring frame (which is identical to the lower frame except that it is inverted) will now be installed and mechanically fastened.

LOX Tank Emplacement — Using the toroidal tank handling fixture, the LOX (inner) tank will be lowered into the recess provided in the final assembly fixture.

LH_2 Tank and Hanger Assembly — The 30-degree segments of the glass fiber/resin hanger skirt will be spliced together at their centers leaving the top and bottom free to adjust to slight differences in torus tank diameters. Using a handling tool, the skirt will be lifted into place around the LOX tank and held with the base diameter parallel to the base diameter of the LOX tank. Locators will provided in the fixture for this purpose. Next, using an indexing template, the attach pilot holes will be drilled through the spherical bearing in the skirt and into the LOX tank. Both parts will be marked. The skirt will be removed, and holes in the tank will be tap-drilled and tapped. All holes will then be deburred. Then the skirt will be moved to the LH_2 tank final assembly position where the skirt is located to a reference plane by locating blocks (integral parts of the fixture). Holes will be drilled, tapped and deburred as before, and fasteners will be installed.

LH_2 Tank Emplacement — Using the torus tank handling fixture, the LH_2 tank with skirt attached will be moved into its recess in the final assembly fixture. The hanger skirt spherical bearing holes will be indexed to the mark to the corresponding LOX tank holes. Fasteners will then be installed.

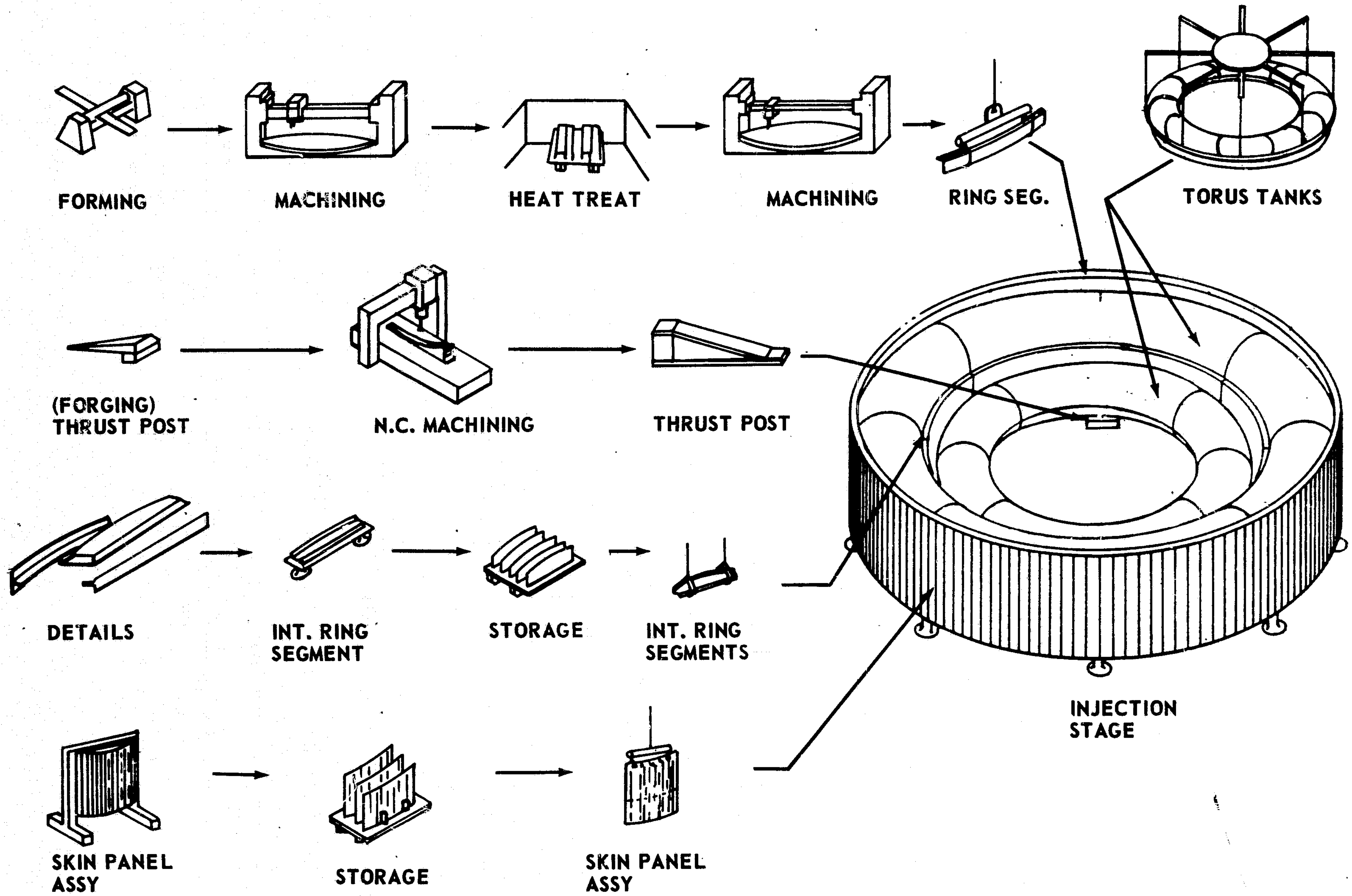


FIGURE 5.3.3.10-1 FINAL ASSEMBLY SEQUENCE

5.3.3.10 (Continued)

Skin Cylinder Assembly — The 12 preassembled skin panels will be indexed against the ring frames and attach holes at the rings and LH_2 tank are drilled. The panels will be removed, deburred, and the LH_2 tank attach holes tapped. The spherical bearing assemblies will be pressed into the bearing fittings in the panels. The panels will then be relocated and mechanically fastened. Panel splice doublers and hat sections will be installed at the skin splices. The pin connections will be made between the LH_2 tank and the outer shell spherical bearings. The top interface ring frame segments will be located, joined and installed. The propellant tunnels, miscellaneous bracketry and access doors will also be installed.

Tank Insulation — With a handling tool, the stage will be lifted vertically from the assembly fixture and moved to a turntable where the tank is coated with foam insulation (only if the injection stage is scheduled for no more than two or three orbits). If both injection stage and main stage are built at the same location, foam can be applied on the same turntable used for the main stage. The stage will be set upright on support stands located around the base periphery of the outer shell. A boom fitted with a tracked sprayer will extend over the tanks. As the assembly is rotated on the turntable the spray gun will apply foam to the tanks.

Painting — The outer skin will be masked and painted. This will be accomplished using a movable enclosure with a fume exhaust system. This enclosure will surround 20 feet of skin section. When the paint is dry, the assembly will be turned and a new section will be painted.

Engine and Systems Installation — When the spray has been applied to the toroidal tanks, the assembly will be moved to the engine installation area where it is placed over the heat shield. The lower edge of the injection stage will rest on peripheral pedestals, shown on Figure 5.3.3.10-2, similar to those used at the foaming station. The heat shield will be adjusted into position, with the jackscrew located peripherally under the structure. The remaining portions of the support frames will be installed at this time. Ring clamps and predrilled angles will be attached. Using appropriate drill jigs, all remaining attach-holes will be drilled and deburred. Next the remaining heat shield honeycomb panels will then be fitted to the frame. The bare edge of the honeycomb will be covered with Refrasil and fastened into place.

The engine will then be mounted vertically on dollies which can be moved , raised, or lowered as desired. The dollies will be positioned under the assembly, Figure 5.3.3.10-3, and each engine will be raised into place for mating to the engine mount.

Using the engine dollies with adapters, flexible heat shields will be raised into position and fitted to the engine nozzles. They will then be removed, marked and shipped with the other heat shield panels. The TVC actuators and other system components will then be installed.

The injection stage will then be ready for shipment to the static firing (launch) site.

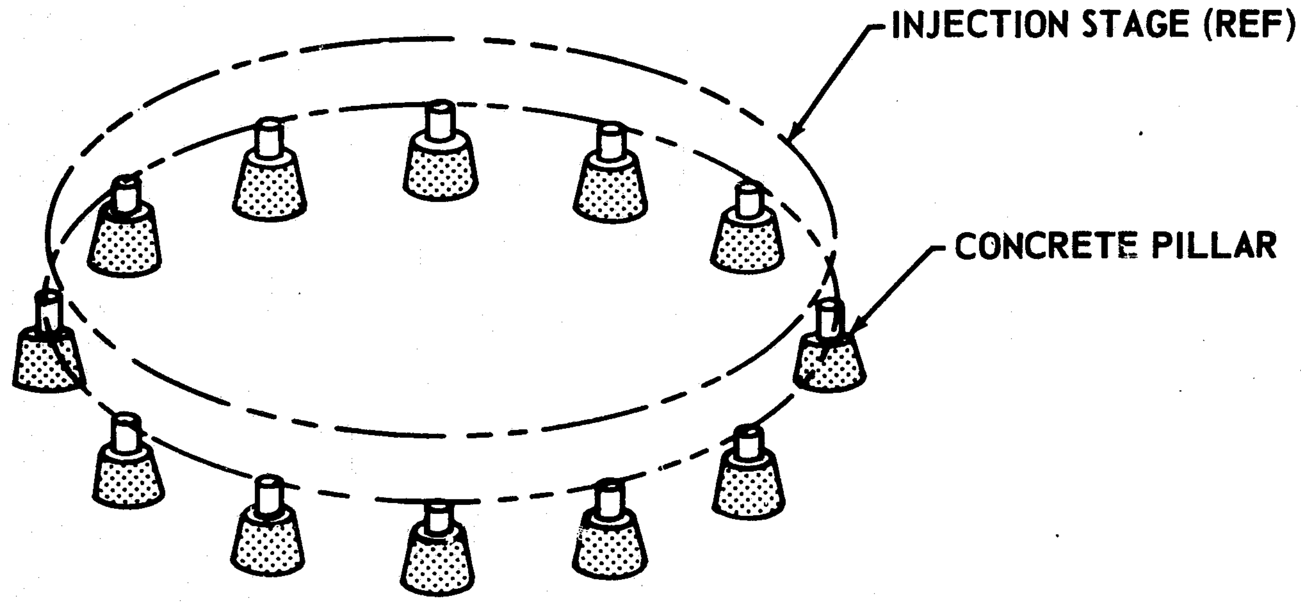


FIGURE 5.3.3.10-2 INJECTION STAGE PICKUP STATION

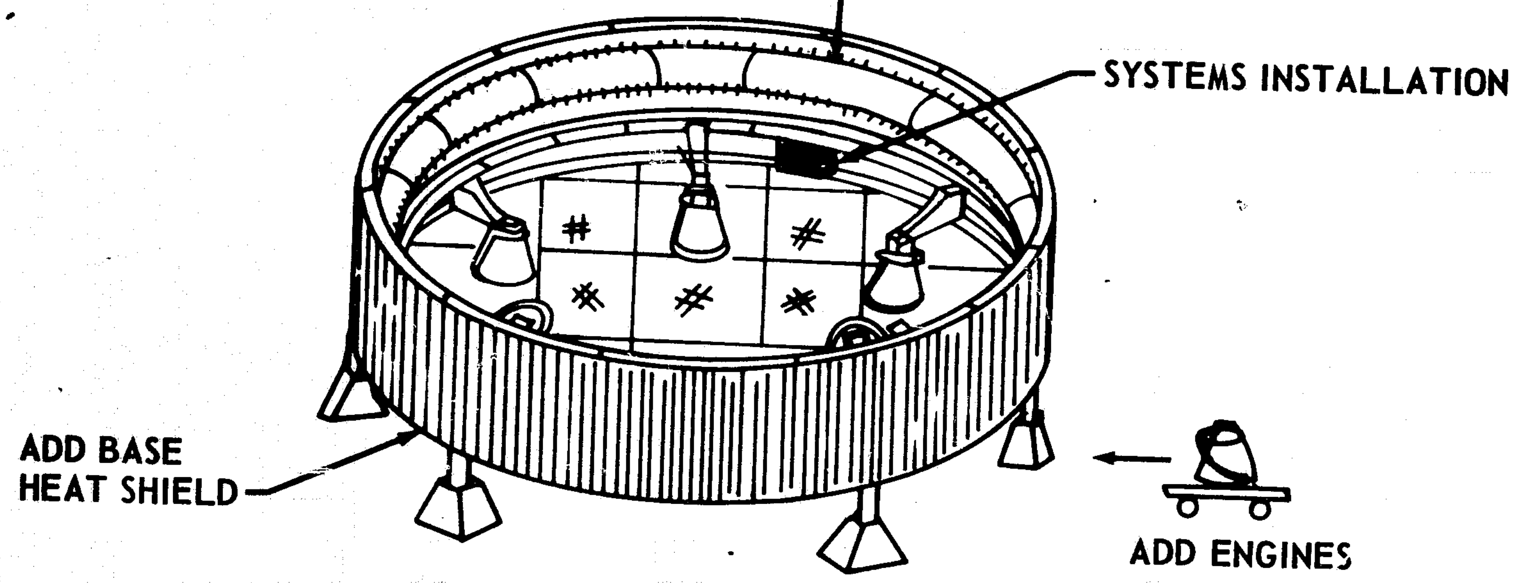


FIGURE 5.3.3.10-3 BASE HEAT SHIELD AND ENGINE INSTALLATION

5.3.3.10 (Continued)

Assembly of Additional Modules — Additional modules will be assembled in the same manner as the lower module except that no engine heat shield installation will be required. Access platforms will be needed to attach intertank feed lines which are rolled into position on dollies in a similar manner to the engines. Modules will be stacked as required at the launch site.

5.3.3.11 Systems Fabrication

The systems required for the injection stage, by type and subsystem in each are listed below:

System Type	Subsystem
Electrical Power and Network	Power Subsystem Distribution and Network Subsystem
Communication and Tracking	Command Subsystem C-Band Transponder Subsystem
Data Systems	Measurement Subsystem Emergency Detection Subsystem Telemetry Subsystem On Board Test and Checkout Subsystem
Guidance and Control System	Guidance Subsystem Steering Control Subsystem Flight Sequencing Subsystem

Systems description for the injection stage, by storable items and systems reference is given below:

Package No.	Item Content	System Reference	Subsystem Reference
No. 1	Duplexer Power Divider Ordnance Firing Unit Command Receiver Command decoder Container Top Bottom Cable Assembly, 5 each Coax Cable Coax Connectors, 10 each	Communication System	Command Subsystem

5.3.3.11 (Continued)

Package No.	Item Content	System Reference	Subsystem Reference
No. 2	Antenna		Command Subsystem
	Bracket plate		
No. 3	Antenna		Command Subsystem
	Bracket plate		
No. 4	Power Divider		C-Band Transponder Subsystem
	Transponder		
	Cable assemblies, 2 each		
	Connectors, 4 ea.		
	Coax. Cable		
	Container		
	Top		
	Bottom		
No. 5	Antenna		C-Band Transponder Subsystem
	Bracket plate		
No. 6	Antenna		
	Bracket plate		
No. 7	Computer	Guidance and Control Subsys.	Guidance and Control Subsystem
	Precision Plate		
No. 8	Battery, 2 ea.	Electrical and Power Network	Power Subsystem
	Measurement Power Supply		
	Container		
	Top		
No. 9	Main Power Distr.		Distributor-Network Subsystem
	Case		
	Cover		
	Wire Bundle		
	Connectors, 14 ea.		
	Wire, 14 ea.		
	Lacing Bars		
	Relay Bracket Assy.		
	Bracket		
	Relays, 20 ea.		
	Printed Circuit Card, 4 ea.		

5.3.3.11 (Continued)

Package No.	Item Content	System Reference	Subsystem Reference
	Card (phenolic) Connector Resistor, 10 ea. Capacitor, 5 ea. Transistors, 5 ea. Diodes, 5 ea. Switch Selector Bus Bars, 5 ea. Cable Assembly, 10 ea. Wire Connectors, 20 total		
No. 10	Secondary Power Supply, 2 ea. Case Cover		Distributor-Network Subsystem
No. 11	Printed Wiring Assy., 10 ea. Card (phenolic) Resistors, 10 ea. Capacitors, 5 ea. Transistors, 10 ea. Diodes, 5 ea. Connector Bus Bar, 5 ea. Lacing Bar, 5 ea. Relay Assembly Bracket Relay, 10 ea. Cable Assemblies, 30 total Connectors, 60 total Wire Container Top		
No. 12	Umbilical Elect. Plate		Distributor-Network Subsystem
No. 13	Interstage Elect. Plate		Distributor-Network Subsystem
No. 14	Transducers, 35 ea. Signal Conditioners, 35 ea. Cable Assemblies, 35 ea.		Data Systems Measurement Subsystem

5.3.3.11 (Continued)

Package No.	Item Content	System Reference	Subsystem Reference
No. 15	Test Point Selector Assembly		On Board Test and Checkout Subsystem
	Selector Switch		
	Case		
	Top		
	Wire Bundle		
	Wire		
	Connectors, 22 ea.		
	P.C. Cards, 8 ea.		
	Card (Phenolic)		
	Resistors, 6 ea.		
	Capactiors, 5 ea.		
	Transistors, 5 ea.		
	Connector		
	Programmer		
	Cables, 14 ea.		
	Wire		
	Connectors, 28 ea.		
No. 16	PCM/FM Assembly		Telemetry Subsystem
	128 Multiplexer		
	S. Band RF Assembly		
	Power Divider		
	Cable Assembly, 4 ea.		
	Wire		
	Connectors, 8 ea.		
	Container		
	Top		
	Coax Cable, 3 ea.		
	Coax		
	Connector, 6 ea.		
	Pack		
No. 17	Antenna		Telemetry Subsystem
	Bracket (plate)		
No. 18	Antenna		Telemetry Subsystem
	Bracket (plate)		

5.3.4 Injection Stage Resource Implications

The injection stage resource implications can be divided into five major subsections. These are manpower, materials, tooling, capital equipment and facilities.

5.3.4.1 Injection Stage Fabrication - Recurring Manufacturing Manpower Estimates

These estimates were based on S-IC experience, as the vehicles being costed are similar in materials and type of construction. The estimates were prepared for the 10th unit and factored up the learning curve to obtain the first unit value.

Tables 5.3.4.1-I through 5.3.4.1-III summarized the direct manufacturing manhour estimates for the 2-, 4- and 6-engine modules, for the AMLLV and MLLV vehicles, respectively. Table 5.3.4.1-IV summarized the manufacturing manhours for a single fuel module. These manhours are grouped to permit selection of the combination chosen for the first unit injection stage, which will be defined as that employed on the first flight test vehicle. Costs have been factored on a learning curve of 83 percent for the 10th unit.

As shown in Tables 5.3.4.1-I through 5.3.4.1-IV, the manhours may be subdivided into those required for structure, engine installation and system installation. The method of obtaining the manhour requirement is presented below for the single module configuration.

Single Module Injection Stage - Structure Manhours — The fabrication and assembly of the LH_2 and LOX tanks were estimated considering the time required to cut and trim, form, and weld the tank panels. Most of the other fabrication and assembly activities were estimated by comparing two similar activities performed on the S-IC stage. Other cost elements for the injection stage were not estimated to these elements; therefore, they were regrouped and projected to the first unit (using the 83 percent learning curve).

TABLE 5.3.4.1-I MANUFACTURING MANHOURS (RECURRING) FOR INJECTION STAGE 2-ENGINE MODULE, AMLLV AND MLLV

ITEM			PRODUCTION MANHOURS	
			AMLLV	MLLV
STRUCTURES				
	AMLLV	MLLV		
Skirt	38,935	24,529		
LOX Tank	59,181	37,284		
LH_2 Tank	78,704	49,584		
Thrust Structure	41,427	26,099		
Tunnels	19,000	15,010		
Manhour Totals	237,247	149,466	237,247	149,466
PROPULSION/ MECHANICAL			69,281	69,281
ELECTRICAL/ ELECTRONICS			67,559	67,559
INSTRUMENTATION			27,474	27,474
FLIGHT CONTROL			7,802	7,802
ASSEMBLY			74,132	58,464
ENGINE INSTALLATION, TWO ENGINES			2,706	2,706
TOTAL MANHOURS			486,201	382,752

TABLE 5.3.4.1-II MANUFACTURING MANHOURS (RECURRING) FOR INJECTION STAGE 4-ENGINE MODULE, AMLLV AND MLLV

ITEM			PRODUCTION MANHOURS	
			AMLLV	MLLV
STRUCTURES				
	AMLLV	MLLV		
Skirt	38,935	24,529		
LOX Tank	59,181	37,284		
LH_2 Tank	78,704	49,584		
Thrust Structure	41,427	26,099		
Tunnels	19,000	15,010		
Manhour Totals	237,247	149,466	237,247	149,466
PROPULSION/ MECHANICAL			85,884	85,885
ELECTRICAL/ ELECTRONICS			83,501	83,501
INSTRUMENTATION			38,023	38,023
FLIGHT CONTROL			10,798	10,798
ASSEMBLY			74,132	58,564
ENGINE INSTALLATION, FOUR ENGINES			5,412	5,412
TOTAL MANHOURS			534,997	431,649

5.3.4.1 (Continued)

TABLE 5.3.4.1-III MANUFACTURING MANHOURS (RECURRING) FOR INJECTION STAGE 6-ENGINE MODULE-AMLLV AND MLLV

ITEM			PRODUCTION MANHOURS*	
			AMLLV	MLLV
STRUCTURES				
	AMLLV	MLLV		
Skirt	38,935	24,529		
LOX Tank	59,181	37,284		
LH_2 Tank	78,704	49,584		
Thrust Structure	41,427	26,099		
Tunnels	19,000	15,010		
Manhour Totals	237,247	149,466	237,247	149,466
PROPULSION/ MECHANICAL			128,561	128,561
ELECTRICAL/ ELECTRONICS			125,117	125,117
INSTRUMENTATION			54,947	54,947
FLIGHT CONTROL			15,604	15,604
ASSEMBLY			74,132	58,564
ENGINE INSTALLATION, SIX ENGINES			8,118	8,118
TOTAL MANHOURS			643,726	540,377

* Manhours are for the engine module + installation of six engines.

5.3.4.1 (Continued)

TABLE 5.3.4.1-IV MANUFACTURING MANHOURS (RECURRING) FOR INJECTION STAGE FUEL MODULE, AMLLV AND MLLV

ITEM			PRODUCTION MANHOURS*	
			AMLLV	MLLV
STRUCTURES				
	AMLLV	MLLV		
Skirt	38,935	24,529		
LOX Tank	59,181	37,284		
LH_2 Tank	78,704	49,584		
Thrust Structure	(Not Required)			
Tunnels	19,000	11,970		
Manhour Totals	195,820	123,367	195,820	123,367
PROPULSION/ MECHANICAL			10,000	10,000
ELECTRICAL/ ELECTRONICS			10,000	10,000
INSTRUMENTATION			N/A	N/A
FLIGHT CONTROL			N/A	N/A
ASSEMBLY			48,920	38,647
TOTAL MANHOURS			264,740	182,014

* Manhours are for one fuel module.

5.3.4.1 (Continued)

Single Module Injection Stage - Engine Installation — The estimate for the engine installation time is based on S-IC actual manhours for its engine installation. Although the engine is considerably smaller, it still has about the same number of connections and interfaces. Estimate was made using the following:

S-IC manhours = 6764

Formula:

$$\frac{\text{No. engine (3 module configuration)}}{\text{No. S-IC engines}} = \frac{6}{5} = 1.2$$

Single module configuration = 2706 manhours
Two module configuration = 5412 manhours
Three module configuration = 8118 manhours

Since both the AMLLV and MLLV have the identical number of engines per module, these manhours are equally applicable.

Injection Stage System Installation — Most of the systems will be contained in the lower module (i.e., engine module). Each of the fuel modules will have its own pressurization system and a limited amount of instrumentation. Shown below in Table 5.3.4.1-V are the manhours for the systems installation for the AMLLV and MLLV. These hours are the same, since the identical number of systems are used and the degree of complexity is unchanged with size.

5.3.4.2 Injection Stage Fabrication - Nonrecurring Manufacturing Manpower Estimates

Estimates for manufacturing and engineering labor for get ready costs were prepared. Table 5.3.4.2-IV summarizes the AMLLV and MLLV direct manhours. These estimates do not include the manhours associated with facility (brick and mortar, capital equipment) construction and installation. The rationale used in preparing these estimates is based on S-IC experience, and options of knowledgeable personnel in manufacturing test and tooling.

TABLE 5.3.4.1-V AMLLV INJECTION STAGE SYSTEM INSTALLATION

Systems Installed*	MANHOURS Single Module	Two Modules	Three Modules
Propulsion/ Mechanical	69,281	95,884	138,561
Electrical	67,559	93,501	135,117
Instrumentation	27,474	38,023	54,947
Flight Control	7,802	10,798	15,604
Unit No. 1-Totals	172,116	238,206	344,229

* Systems listed are those installed on Production Unit No. 1 of the single module injection stage configuration.

TABLE 5.3.4.2-IV SUMMARY OF NONRECURRING THREE MODULE INJECTION STAGE CONFIGURATION - DIRECT MANUFACTURING MANHOUR ESTIMATES

Injection Stage Items	Direct Manhours AMLLV	Direct Manhours MLLV
Engine Installation GSE	21,694	21,694
Engine Installation Planning	6,942	6,964
GSE - Fab and Erect	260,514	218,061
Tool and Production Plan	1,060,544	726,464
Tool Fab and Erect	2,392,000	1,506,960
Tool Design	903,218	573,843
Manufacturing Development	104,668	71,511
Total Manhours	4,749,580	3,125,497

5.3.4.3 Injection Stage Structures Material - Recurring

The injection stage structural material costs are based on average dollar-per-pound value of the S-IC forward skirt, LOX tank and fuel tank. This is considered the most logical means of obtaining a dollar-per-pound value since the injection stage is composed of three structures fabricated from materials common to the above S-IC structures.

Material dollars (AMLLV) were estimated as follows:

Formula:

$10.01 = Avg. dollar-per-pound value of the S-IC forward skirt, LOX tank and fuel tank

83,868 lbs. weight of AMLLV injection stage (less systems wgt)

x $10.01

$847,017 material cost AMLLV injection stage structure .

The above is for a single AMLLV lower module. For the upper modules, a material cost of $540,711 per module was used.

Material dollars (MLLV) were estimated as follows:

Formula:

$10.01 = Avg. dollar-per-pound value of the S-IC forward skirt, LOX tank and fuel tank

43,522 lbs. weight of MLLV injection stage (less systems wgt)

x $10.01

$439,568 material cost MLLV injection stage structure .

The above is for a single MLLV lower module. For the upper modules, a material cost of $282,602 per module was used.

5.3.4.4 Injection Stage Systems Materials

Recurring — Material dollars based on a ratio of S-IC engines to those of the injection stage. This ratio is applied to all systems of the S-IC that are common to those of the injection stage. All systems are considered comparable with the exceptions of the LOX and fuel delivery systems. The AMLLV injection stage system material costs were computed as follows:

5.3.4.4 (Continued)

Comparable material dollars S-IC systems

	$4,242,822	total S-IC systems
-	1,388,786	total LOX delivery system
-	865,644	total fuel delivery system
	$1,999,392 ;	

Ratio: $\frac{\text{Injection Engines}}{\text{S IC Engines}} = \frac{6}{5} = 1.2$;

Material cost injection stage (AMLLV)

$1,999,392
x 1.2

$2,399,270 Total for three module AMLLV injection stage;

$1,799,453 for two module AMLLV injection stage;

$1,199,636 for single module AMLLV injection stage.

For the MLLV, the injection stage system material costs were computed as follows:

a. For the single module injection stage system materials - $1,079,624;
b. For the two module injection stage system materials - $1,644,483;
c. For the three module injection stage systems materials - $2,209,343.

Nonrecurring Injection Stage MGSE Materials Cost — Based on a size ratio with the S-IC material costs were computed as follows:

Material cost S-IC	$3,345,269
Size ratio	.3
Material Cost	$1,003,580.

The MGSE costs for the AMLLV and MLLV are identical.

5.3.4.5 Injection Stage Tooling Materials - Nonrecurring

Nonrecurring injection stage tooling materials costs were computed as follows:

AMLLV Material Dollars	MLLV Material Dollars
2,881,260 Manhour tool production	1,815,204 Manhours tool production
x $1.75 per production manhour	x $1.75 per production manhour
$5,042,205 Tooling material dollars	$3,176,607 Tooling material dollars .

5.3.4.5 (Continued)

Table 5.3.4.5-I itemizes the elements making up these totals, and also includes the non-recurring cost of GSE.

5.3.4.6 Injection Stage Tooling

The tooling lists which follow identify the manufacturing tooling necessary to fabricate the injection stage. For the major tooling items, the tooling concept is illustrated. Table 5.3.4.6-I itemizes the manhours for fabrication and erection of tooling used to build all modules.

LH_2 Tank Tools — The LH_2 and LOX torus tank of the injection stage are similar in configuration and structure, differing only in size. The manufacturing sequences required to produce these tanks will be almost identical. In describing these sequences, the LH_2 tank was taken as the typical example. The LOX tank assembly sequence was presented as a matter of format and its context was referenced to the LH_2 tank assembly where fabrication plans are the same. Following are tool lists for both tanks. This section contains listings of the subassembly tooling and major assembly tooling required to manufacture the LH_2 tank assembly. Some of the detail tooling required to produce the subassemblies is also included, along with the function of all the tools.

LH_2 manifold ring with manifold fittings:

TOOL	FUNCTION
Major assembly fixture	This tool is used to hold the LH_2 ring segments together for welding and trimming
Stretch form die	Used to form manifold ring segments
LH_2 ring segment handling tool	Used for moving the LH_2 segments to the major assembly fixture
Trim fixture	Used to hold segments for end trimming
LH_2 ring handling tool	Used to move LH_2 manifold ring assembly to LH_2 tank assembly fixture

TABLE 5.3.4.5-I INJECTION STAGE TOOLING MATERIAL REQUIREMENTS - NONRECURRING AMLLV AND MLLV

ITEM			AMLLV	MLLV
STRUCTURES				
	AMLLV	MLLV		
Skirt	1,107,015	697,419		
LOX Tank	376,058	236,917		
LH_2 Tank	1,012,725	638,017		
Thrust Structure	1,392,300	877,149		
Tunnels	67,568	42,567		
Totals	3,955,666	2,492,069	$3,955,666	$2,492,069
PROPULSION/ MECHANICAL			849,940	535,462
ELECTRICAL/ ELECTRONICS			44,135	27,806
INSTRUMENTATION			41,633	26,246
FLIGHT CONTROL			150,833	95,025
Sub Total			$5,042,217	$3,176,608
GSE			1,003,581	1,003,581
			$6,045,798	$4,180,189

TABLE 5.3.4.6-I INJECTION STAGE TOOL FABRICATION AND ERECTION MANPOWER REQUIREMENTS, NONRECURRING - AMLLV AND MLLV

ITEM			AMLLV	MLLV
STRUCTURES				
	AMLLV	MLLV		
Skirt	632,580	398,525		
LOX Tank	214,890	135,381		
LH_2 Tank	578,700	364,581		
Thrust Structure	795,600	501,228		
Tunnels	38,610	24,324		
Structures Totals			2,260,380	1,424,039
PROPULSION/ MECHANICAL			485,680	305,978
ELECTRICAL/ ELECTRONICS			25,220	15,889
INSTRUMENTATION			23,790	14,998
FLIGHT CONTROL			86,190	54,300
Sub Total			2,881,260	1,815,204
GSE FAB & ERECTION			260,514	218,061
TOTAL MANHOURS			3,141,774	2,033,265

Note: These tools build all injection stage modules.

5.3.4.6 (Continued)

TOOL	FUNCTION
Drain fitting handling tool	Used to position manifold fittings on ring segment and manifold ring

Outer T-ring LH_2 tank:

TOOL	FUNCTION
Ring segment handling tool	Used to transfer ring segments to ring assembly fixture
Trim fixture	Used to hold ring segments for trimming ring segment ends prior to welding
Outer T-ring assembly fixture	Major assembly fixture for holding ring segments together for welding
Ring handling tool	Used to move outer T-ring assembly to next assembly

Inner T-ring LH_2 tank:

TOOL	FUNCTION
Ring segment handling tool	
Trim fixture	
Inner T-ring assembly fixture	Major assembly fixture for holding ring segments together for welding
Ring handling tool	Used to move inner T-ring assembly to next assembly

Section splice segments LH_2 tank:

TOOL	FUNCTION
Segment handling tool	Used to transfer segments to assembly position
Trim fixture	Used to hold segments for end trimming operations

5.3.4.6 (Continued)

Shear web LH_2 tank:

TOOL	FUNCTION
Major assembly fixture	Used to hold web skin, doubler and hat sections for riveting operations
Shear web handling tool	Used to position web inside torus tank assembly
Form die	Used to make joggle in shear web

LH_2 tank skins:

TOOL	FUNCTION
Handling tool	Used to transfer formed tank skins into assembly fixture
Bulge form die	Used to form upper and lower section halves of torus segment

Major assembly tools:

TOOL	FUNCTION
Final assembly fixture, LH_2 tank	Used to hold tank segment in position for welding and assembly of tank
LH_2 tank handling tool	Used to move LH_2 tank to final assembly and other stations

Miscellaneous tools are those tools coded according to function but cannot be classified as dies, jigs, fixtures or mechanical equipment. These tools include:

a. Drill tools - special drill bits, reamers, etc.;

b. Form cutting tools - special cutting tools required for use on lathes, milling machines, etc.;

c. Standard tools - tools not limited to specific parts or assemblies such as tube bending tools, burring tools, wrenches, etc.

LOX Tank Assembly Tools — This section contains a listing of the subassembly and major assembly tools required for the fabrication of the LOX torus tanks. The function of each tool is also given.

5.3.4.6 (Continued)

LOX manifold ring with fittings:

TOOL	FUNCTION
Major assembly fixture	Used to hold the LOX ring manifold segments for welding
Stretch form die	Used to form the LOX ring segments
LOX ring segment handling tool	Used for moving the LOX ring segments to the major assembly fixture
Trim fixture	Used to hold ring segments for end trimming
LOX ring handling tool	Used to move LOX manifold ring assembly to the LOX tank assembly fixture
Drain fitting handling tool	Used to position manifold fittings on ring segments and on manifold ring assembly

Inner T-Ring, LOX tank:

TOOL	FUNCTION
Ring segment handling tool	Used to transfer ring segments to ring assembly fixture
Trim fixture	Used to hold ring segments for trimming ends
Assembly fixture	Used to hold ring segments for welding inner T-ring
Ring handling tool	Used to move ring assembly to torus tank assembly fixture

Outer T-Ring LOX tank:

TOOL	FUNCTION
Ring segment handling tool	Used to transfer ring segments to ring assembly fixture
Trim fixture	Used to hold ring segments for trimming ends

5.3.4.6 (Continued)

TOOL	FUNCTION
Outer T-ring assembly fixture	The major assembly fixture for holding ring segments together for welding
Ring handling tool	Used to move ring assembly to torus tank assembly fixture

Section splice segments, LOX tank:

TOOL	FUNCTION
Segment handling tool	Used to transfer segments to assembly position
Trim fixture	Used to hold segments for end trimming operation

Shear webs, LOX tank:

TOOL	FUNCTION
Major assembly fixture	Used to hold web skin, doubler and hat sections for riveting operations
Shear web handling tool	Used to position web assemblies inside torus tank assembly

LOX tank skins:

TOOL	FUNCTION
Handling tool	Used to transfer formed tank skins to assembly fixture
Bulge form die	Used to form skin sections

Major assembly tools:

TOOL	FUNCTION
Major assembly fixture	Used to hold manifold ring and tank skins for assembly of torus tank
LOX tank handling tool	Used to move LOX torus to final assembly and to other stations

5.3.4.6 (Continued)

Miscellaneous tools are identical to those miscellaneous tools for the LH_2 tanks.

Skin panel assembly tools. — The following tools are required to fabricate skin panel assemblies:

TOOL	FUNCTION
Skin panel assembly fixture	Used to build up the complete subassembly from skins and hat sections
Personnel platform	Used to provide access to the skin panel subassembly fixture
Skin segment NC tapes	Numerical control tapes for machining the skin
Hat section hoisting tool	Used to hoist hat section stiffeners in and out of the subassembly jig
Hat section drill plate	Used to locate fastener holes in hat section
Skin panel hoisting tool	Required to handle large skin panels
Skin panel assembly hoisting tool	Required to handle skin panel subassemblies

Thrust Ring Segment Tooling — The following tools are required to fabricate the upper and lower ring assembly:

TOOL	FUNCTION
Upper ring segment subassembly fixture	Required to assemble bonded honeycomb web to inner and outer T-chords, as shown on Figure 5.3.4.6-1
Lower ring segment subassembly fixture	Similar to above
Upper ring track router fixture	Used to hold the face sheets while the correct profile is routed around their edges; also, provides the correct profile track for the router to follow
Lower ring track router	Similar to above

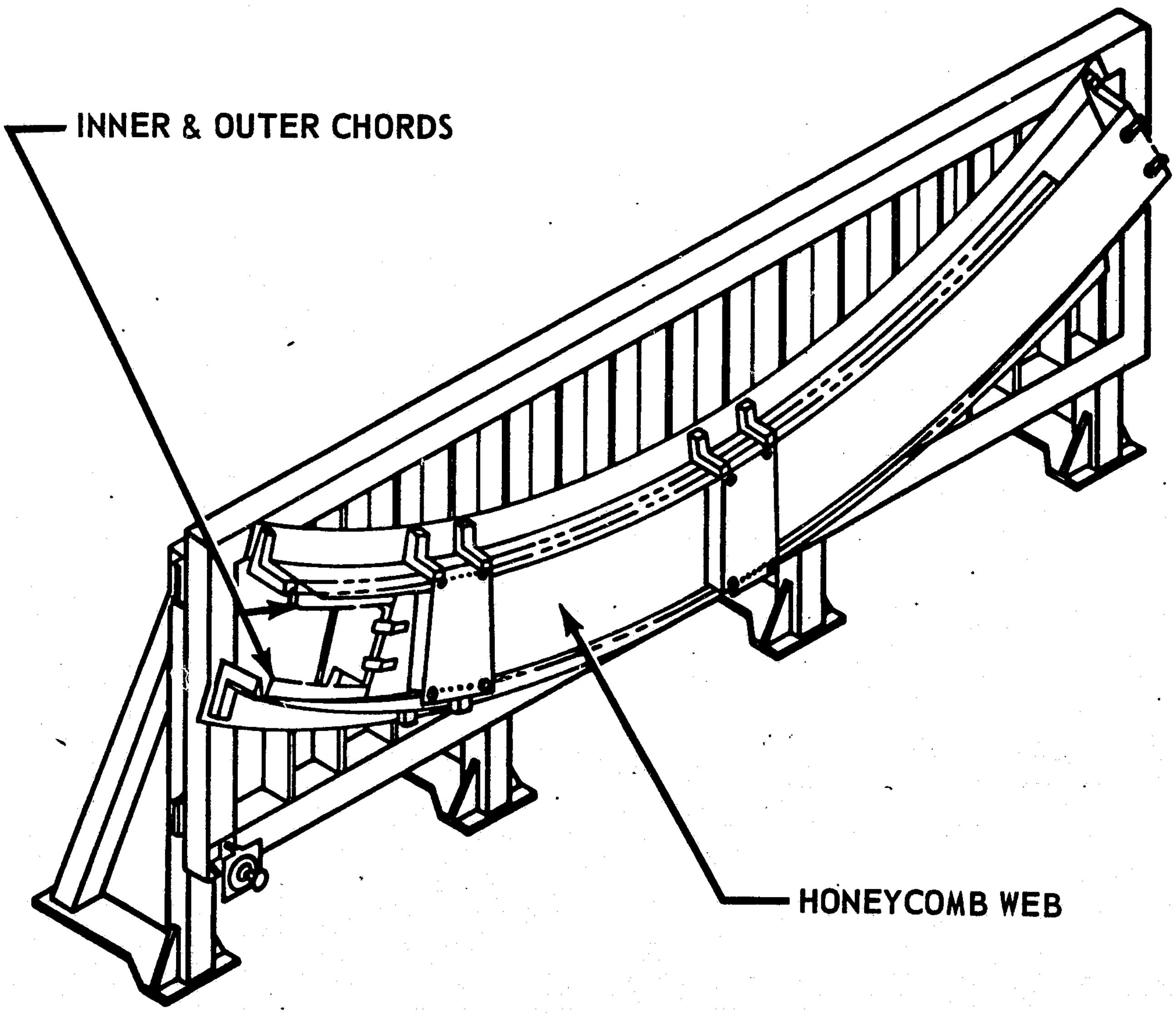


FIGURE 5.3.4.6-1 INJECTION STAGE RING SEGMENT ASSEMBLY FIXTURE

5.3.4.6 (Continued)

TOOL	FUNCTION
Upper ring segment bonding fixture	Holds the face sheets, Z-sections and honeycomb while the adhesive bonding material is being cured in the autoclave
Lower ring bonding fixture	Similar to above
Upper ring track router fixture with polyglycol chuck	Provides a means of stabilizing the edges of the honeycomb during the routing operation, as shown on Figure 5.3.4.6-2
Lower ring track router fixture	Same as above
Upper ring web assembly hoisting tool	Used to transport web assembly, as shown on Figure 5.3.4.6-3
Lower ring web assembly hoisting tool	Same as above
Drill plate	Locates holes for mechanical fasteners in completed segments
Handling tool	Used to lift inner and outer T-chords, as shown on Figure 5.3.4.6-4

Interface ring segment assembly tooling. — The assembly tooling required to fabricate the interface ring segment is as follows:

TOOL	FUNCTION
Stretch form die	Used to form the ring segments
Ring segment handling tool	Used to move the segment to the final assembly fixture
Trim fixture	Used to hold ring segment for end trimming operations

Hanger skirt tooling. -- The tooling required for this ring is as follows:

TOOL	FUNCTION
Segment layup form	Used to layup fiberglass segments to proper contour and shape

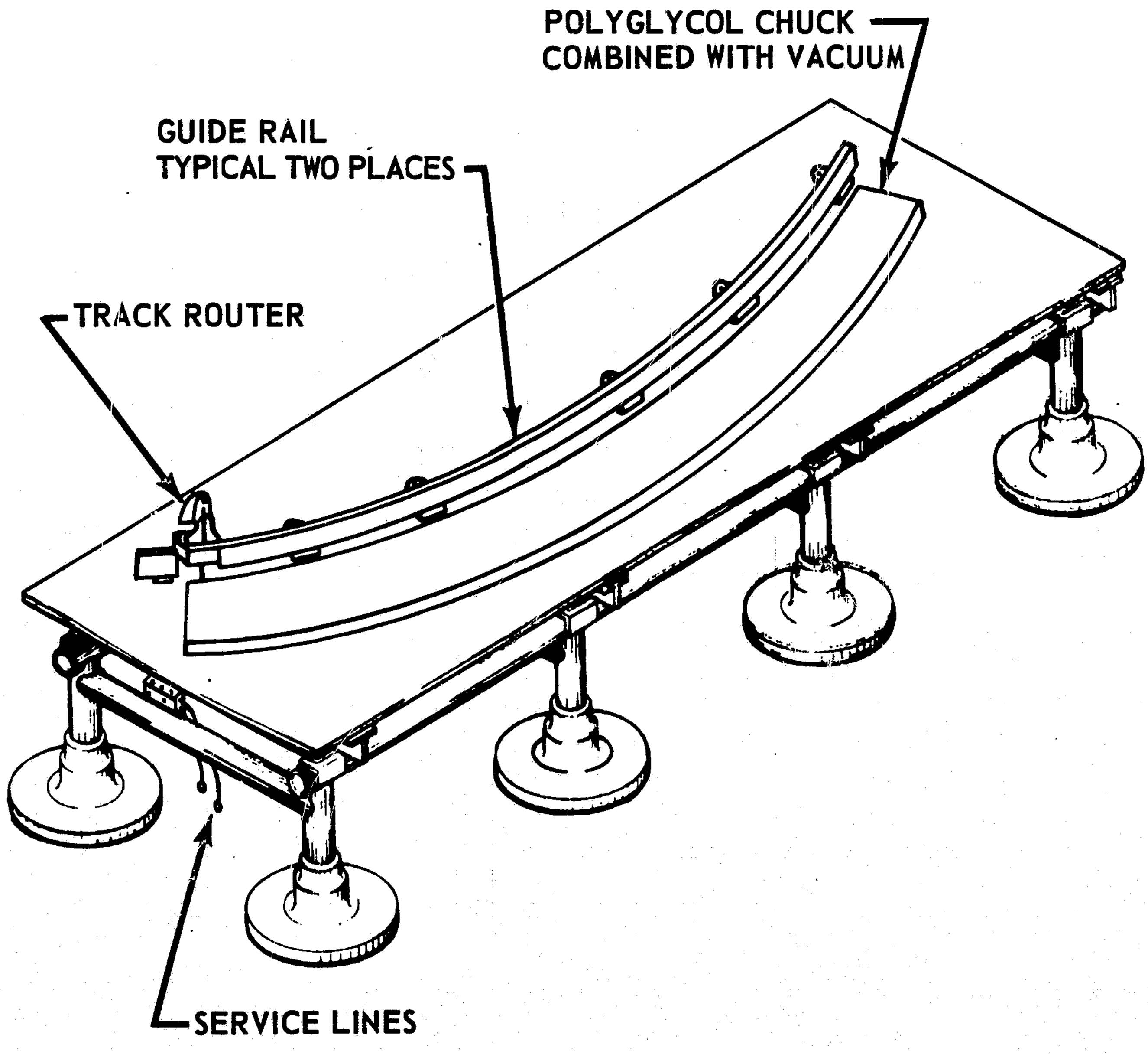


FIGURE 5.3.4.6-2 TRACK ROUTER TABLE WITH POLYGLYCOL CHUCK

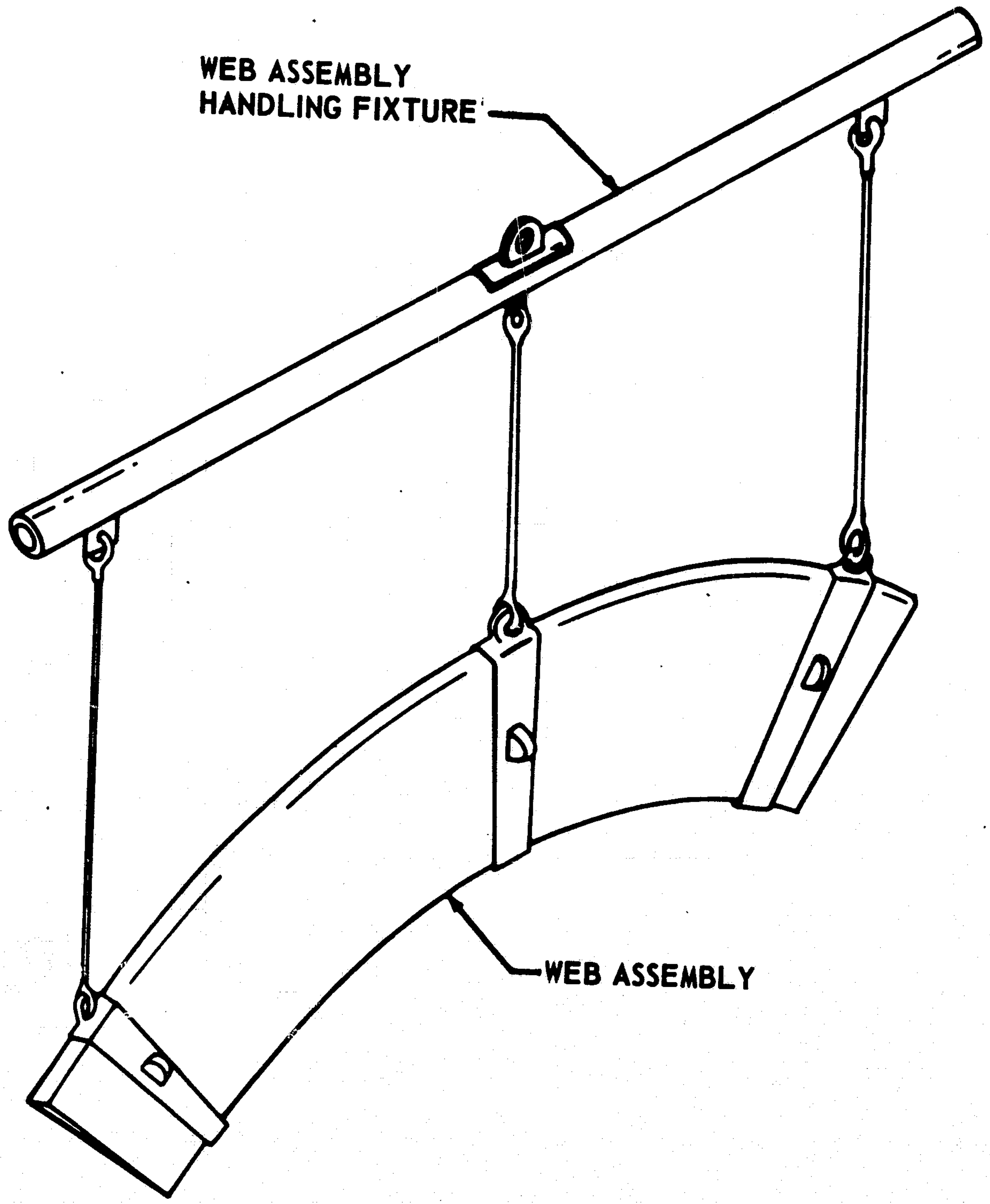


FIGURE 5.3.4.6-3 INJECTION STAGE RING SEGMENT ASSEMBLY HANDLING FIXTURE

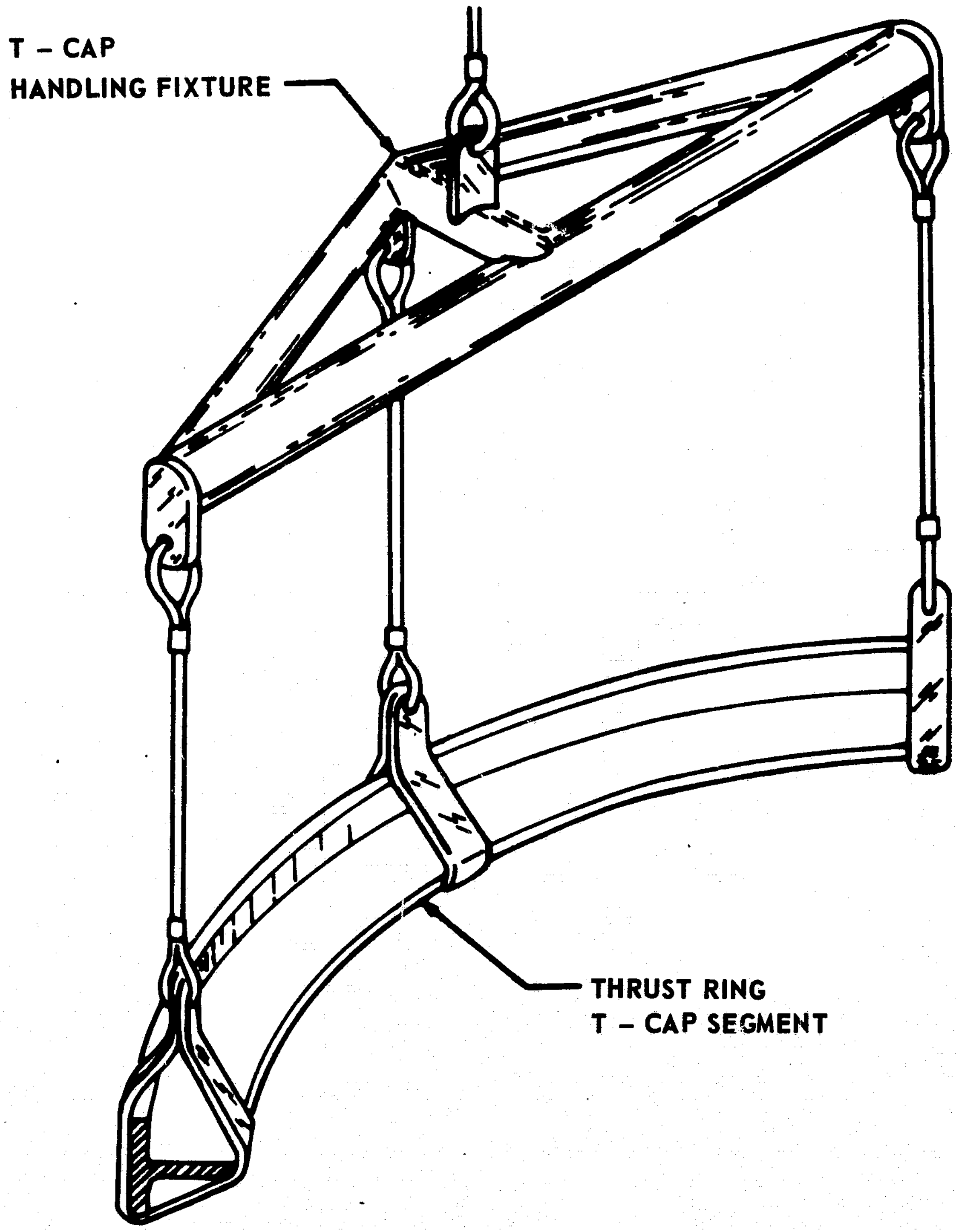


FIGURE 5.3.4.6-4 INJECTION STAGE HANDLING TOOL - INNER AND OUTER CHORDS OF RING SEGMENT SUBASSEMBLY

5.3.4.6 (Continued)

TOOL	FUNCTION
Trim fixture	A holding fixture with a track router for trimming the segments to size
Drill templates	These index to the trim fixture and establish the hole pattern for the spherical bearings

Engine Mount Tooling — Engine mount tooling is as follows:

TOOL	FUNCTION
Engine mount handling tool	Used to place the forging in the final assembly fixture
Special drill bits, reamers, etc.	Used as required
Form cutting tools	Special tools used on lathes, milling machines, etc.

Base Heat Shield — Following is a brief description of tools and capital items. Tools are identified by the subassembly with which they are associated. Capital items are identified by function.

Base Heat Shield Support Structure — The following tools are required to fabricate and assemble the support structure:

TOOL	FUNCTION
Support structure assembly fixture with drill plates	Used to assemble channel and other details into a framework to support the honeycomb panels
Miscellaneous trim fixtures	Used to hold the details for net trimming the ends to length and shape

Heat Shield Honeycomb and Refrasil Panels — These tools are needed for fabrication and assembly of the honeycomb and Refrasil panels:

TOOL	FUNCTION
Track router trim fixture	Used to trim the bonded honeycomb panels net
Bonding fixture	Required for holding sandwiches panels together for bonding in an autoclave

5.3.4.6 (Continued)

TOOL	FUNCTION
Drill templates	These are required for drilling holes for Refrasil attach stud inserts

<u>Heat Shield Assembly Tools</u> — These tools are required for installing the honeycomb and Refrasil panels to the support structure:

TOOL	FUNCTION
Drill templates	Required to establish an attach hole pattern between the honeycomb and support structure
Honeycomb panel handling fixture	Needed to fabricate moving honeycomb panels to heat shield assembly area
Heat shield final assembly tool	Used for holding the support structure for installation of honeycomb and Refrasil panels
Heat shield handling fixture	Used to lift support structure and completed heat shield assembly
Heat shield inverting tool	Used to invert the heat shield for placement into the final assembly station

<u>Final Assembly Tools</u> — A brief description of each tool and capital item follows. Unless otherwise noted all tools are designed specifically for the final assembly of the injection stage. Capital item and general purpose equipment are identified by function.

The following tools are required to assemble the injection stage:

TOOL	FUNCTION
Major assembly fixture	This tool is used for assembling the ring frames, loading and interconnecting propellant tanks, and attaching skin panels as shown on Figure 5.3.4.6-5
Major assembly personnel platforms	These are required to provide access to the major assembly fixture
Pickup position personnel platform	These provide access to the injection stage for engine and systems installation as well as the Refrasil-honeycomb heat shield

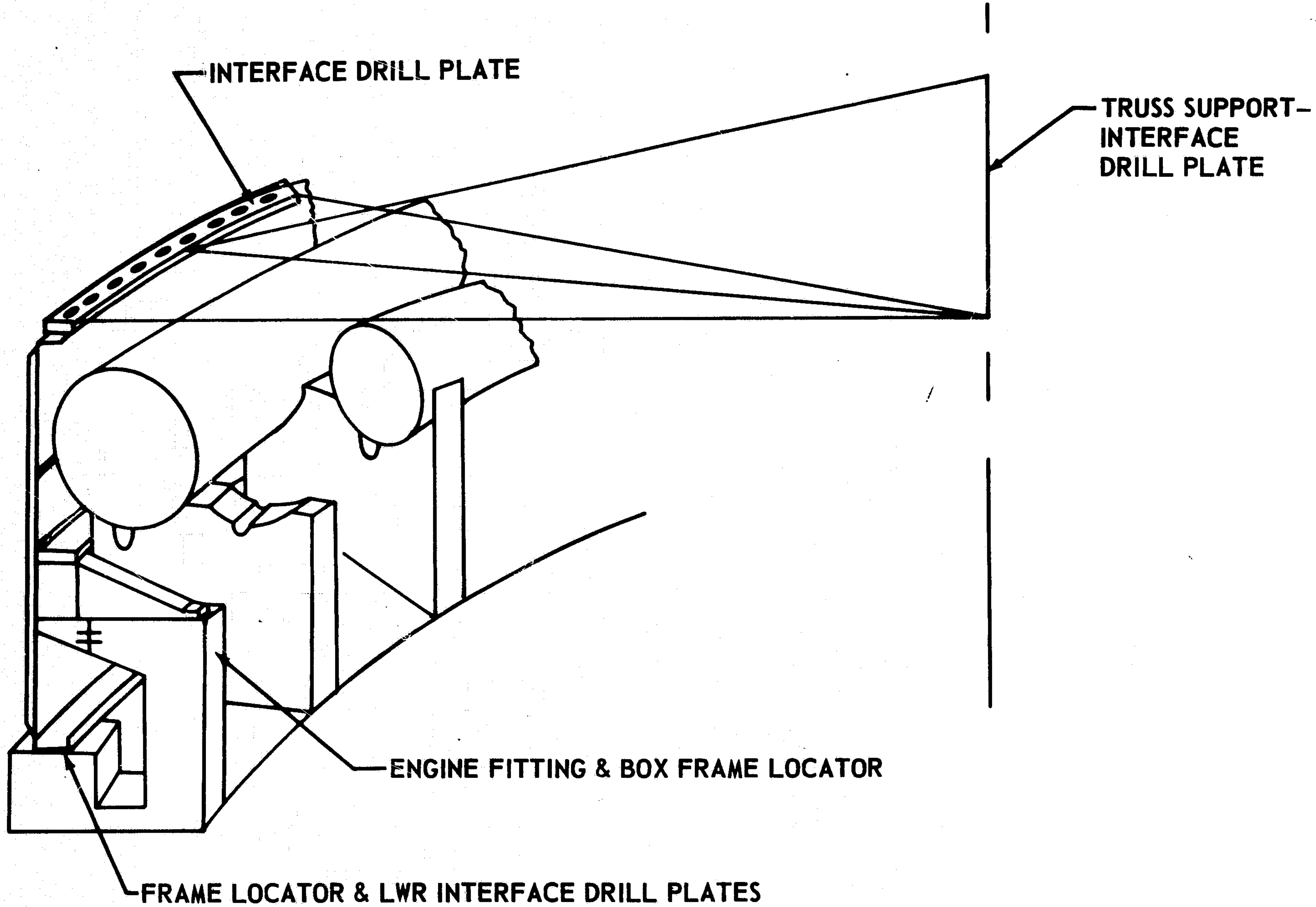


FIGURE 5.3.4.6-5 FINAL ASSEMBLY FIXTURE

5.3.4.6 (Continued)

TOOL	FUNCTION
Major assembly handling tool	To lift the injection stage from one position to another or to the transportation dolly
Major assembly transportation dolly	This dolly is used to move the injection stage to the foaming and painting area
Skin panel handling tool	To provide a means of attaching the overhead crane to skin panels for movement
Ring segment handling tool	To serve the same function as above for holding ring segments
Engine thrust post handling tool	Serves the same function for the thrust post
Base heat shield master gage	To establish a standard hole pattern for the base heat shield panels. This is particularly needed in the event that the base heat shields are purchased
Interface hole pattern master gage	To establish a standard hole pattern between injection stage modules, between modules and payload and between forward skirt and modules
Hanger skirt handling tool	A tool is needed to raise the hanger skirt keeping the edges of each segment in the same place
Torus tank handling tool	LH_2 and LOX tanks must be lifted with the overhead crane. This tool will provide a means of distributing the weight of the tank more evenly
Foam spray fixture with boom	This provides a means of evenly applying plastic foam insulation to the torus tanks
Special purpose paint booth	This ventilated paint spray booth 20 by 20 by 10 ft, is necessary to prevent paint fumes from entering occupied spaces and to provide drying

5.3.4.6 (Continued)

TOOL	FUNCTION
Engine dollies (four required) with adaptors	These dollies transport the injection stage engines and raise them into position. With adaptors they handle ducts and other engine associated hardware
Pedestals	These provide a level base upon which to rest the stage at the foaming station and the pickup position
Support frame mounts	Twelve rigid removable floor mounted pedestals with jackscrews for raising the heat shield into position in the injection stage
Drill templates	Drill templates are used as guides to drill standard hole patterns

Injection Stage Tooling Summary -- Following is a summary listing by structures, LH_2 torus tank, and LOX torus tank of the tooling required to fabricate and assemble the injection stage:

ASSEMBLY	NOMENCLATURE - PURPOSE
Structures	Major assy fixture Major assy pick-up position Skin panel subassy Lwr. ring seg. subassy Box ring seg. subassy Track router - lwr ring seg. web Track router - box ring seg. web Track router with ice chuck - honeycomb Bonding fixture - lwr ring seg. Bonding fixture - box ring seg. Autoclave Personnel platform - major assy Personnel platform - pick-up pos. Personnel platform - skin panel Handling tool - major assy Handling tool - skin panel Handling tool - lwr ring seg. Handling tool - box ring seg. N.C. tape - engine thrust post Bonding fixture - fiberglass strap Master gage - base heat shield

5.3.4.6 (Continued)

ASSEMBLY	NOMENCLATURE - PURPOSE
Structures	Misc. tools (detail)
	Master gage - interface hole pattern
LH_2 torus tank	Tank assy weld fixture
	Manifold seg. subassy
	Bulge form die - tank skin seg.
	Heat treat fixture - tank skin seg.
	Trim fixture - tank skin seg.
	Weld fixture - inner T-ring
	Weld fixture - outer T-ring
	Niles boring mill
	Shear web assy fixture
	Track welder - manifold seg. to seg.
	Track welder - upr. and lwr. tank half to half
	Gantry welder - manifold fitting
	X-Ray equipment
	Handling tool - tank skin seg.
	Handling tool - manifold seg.
	Handling tool - inner and outer T-rings
	Handling tool - tank/manifold assy
	Handling tool - shear web assy
	Personnel platform - tank assy
	Weld clamps
	Master gage - tank contour
	Welder - T-ring to tank halves
	Pick-up position - tank assy
	Trans. trailer - skin seg.
	Misc. tools
	N.C. tape - skin seg.
	Vacuum chucks
LOX torus tank	Tank assy weld fixture
	Manifold seg. subassy weld fixture
	Shear web assy fixture
	Bulge form die - tank skin seg.
	Heat treat fixture - tank skin seg.
	Trim fixture - tank skin seg.
	Weld fixture - inner T-ring
	Weld fixture - outer T-ring
	Niles boring mill
	Track welder - lower tank half to half
	Track welder - manifold seg. to seg.
	Gantry welder - manifold fitting
	X-Ray equipment
	Handling tool - tank skin seg.

5.3.4.6 (Continued)

ASSEMBLY	NOMENCLATURE - PURPOSE
LOX torus tank	Handling tool - manifold seg. Handling tool - T-rings Handling tool - shear web assy Handling tool - tank/manifold assy Personnel platform - tank assy Weld clamps Vacuum chucks Master gage - tank contour Welder - T-ring to tank halves Pick-up position - tank/manifold assy Trans. trailer - skin seg. Misc. tools NC tape - skin seg.

5.3.4.7 Injection Stage Capital Equipment

Shown below by major subassembly requirements are necessary tooling.

LH_2 tank capital equipment:

OPERATION	NOMENCLATURE - USE
Forming	
Buffalo roll	This machine will be used to form the section splice segments
Bulge form machine	Used to form tank skin section halves
Stretch form machine	Used to form the inner and outer T-chords of the torus tank
Machining	
Track router	Used to trim tank skin sections
Auto feed pneumatic drills	These drills will be required in mechanical fastening the shear webs to the torus splice sections
Niles boring mill	Used to machine drain fittings
Drivematic rivet machine	Used for fastening hat section to shear web skin
Heat treating	
Heat treat furnace	Used to heat treat chord segments, splices, skins and drain fittings

5.3.4.7 (Continued)

OPERATION	NOMENCLATURE - USE
Finishing	
Conversion coating and cleaning racks	Used in applying protective finishes to aluminum detail parts

LOX tank capital equipment:

OPERATION	NOMENCLATURE - USE
Forming	
Buffalo roll	This machine will be used to form the LOX tank section splice segment
Bulge form machine	Used to form tank skin section halves
Stretch form machine	Used to form the inner and outer T-chords of the LOX tank
Machining	
Track router	Used to trim tank skin sections
Auto feed pneumatic drills	These drills will be required in mechanically fastening the shear webs to the torus splice sections
Niles boring mill	Used to machine drain fittings
Drivematic rivet machine	Used to fasten hat sections to shear web skin
Heat Treating	
Heat treat fixture	Used to heat treat chord segments, splices, tank skins and drain fittings
Finishing	
Conversion coating and cleaning racks	Used in applying protective finishes to detail parts

Skin Panel Capital Equipment:

OPERATION	NOMENCLATURE - USE
Forming	
Roll 50-ton	A roll of this capacity is required to form the skin panels to contour

5.3.4.7 (Continued)

OPERATION	NOMENCLATURE - USE
Press 100-ton	Required to hot form the joggles in the center of the hat section stringers
Machining	
Band saw	Needed to cut skin panels and hat sections to proper dimensions
NC mill	Required to form the correct profile in the outer surface of the skin
Auto feed pneumatic drill	About four of the drills will be required for the skin panels
Finishing	
Chemical cleaning line	Five 20- by 25- by 5-ft tanks. They will be used for alkaline cleaning detail parts
Waterfall paint spray booth	A manual booth, 30- by 10-ft opening, for spray priming detail parts
Handling	
Crane	A 30-ton overhead bridge crane is required for handling the injection stage skin panel assemblies

Thrust Ring Segment Capital Equipment:

OPERATION	NOMENCLATURE - USE
Forming	
50-ton roll	A roll of this capacity is required to form the T-chords to contour
Buffalo roll	This machine is needed to roll the Z-shape into the honeycomb edge closures of the bonded ring frame shear web
Collet roll	The honeycomb edge closures are rolled to curvature in this machine
Machining	
Band saw	Needed to cut the skin panels and hat sections to length
Boring mill with 72-foot-diameter turntable	Used to machine finish T-chords of the ring frames

5.3.4.7 (Continued)

OPERATION	NOMENCLATURE - USE
Pneumatic track router	Needed to profile shear web face sheets.
Auto feed pneumatic drill	About twelve of these drills will be required for the segments. These drills are used in conjunction with drill templates
Heat Treating	
Autoclave 500°F	25- by 15- by 6-ft, used to bond the ring frame webs
Finishing	
Chemical cleaning line	This will include five 30- by 15- by 7-ft tanks. They will be used for alkaline cleaning, deoxidizing, rinsing and conversion coating detail parts
Waterfall paint spray booth	A manual booth, 30- by 10-ft opening, for spray priming detail parts
Handling	
Crane 30-ton	Required to lift details and finished ring segments
Transportation dolly	Four required to transport and store finished ring segments

Hanger Skirt Capital Equipment:

OPERATION	NOMENCLATURE - USE
Trimming	
Track router	Used to trim the hanger skirt edge
Drilling	
Pneumatic drill	Used for drilling and reaming spherical bearing holes and other attach holes

5.3.4.7 (Continued)

Engine Mount Capital Equipment:

OPERATION	NOMENCLATURE - USE
Forming	The engine mount forging will be a purchased item not requiring any special forming equipment
Machining	
NC milling machine	Used to machine forging
Drill jig	Used to drill attach holes for engine mounting
Finishing	
Conversion coating and cleaning rack	Used in applying protection coating to engine mount forging

Base Heat Shield Capital Equipment:

OPERATION	NOMENCLATURE - USE
Forming	
Brake	Needed to form angles and brackets
Cutting	
Shear	Used to rough-cut honeycomb face sheet panels
Band saw	Used to rough-cut honeycomb panels
Heat treating	
Autoclave	25- by 12- by 6-ft, needed to bond heat shield honeycomb panels
Finishing	
Chemical cleaning line	This will include five 26- by 10- by 5-ft tanks. They will be used for alkaline cleaning, deoxidizing, rinsing and conversions coating detail parts
Waterfall paint spray booth	A manual booth 30- by 10-ft opening, for spray priming detail parts

5.3.4.7 (Continued)

OPERATION	NOMENCLATURE - USE
Handling	
Crane	This 30-ton bridge crane is needed for handling the honeycomb panels, support structure and heat shield assembly
Machining	
Pneumatic track router	Four are required for net profiling honeycomb panels
Pneumatic drills	Four are required for drilling honeycomb panels for insertion of attach inserts and Refrasil attach studs

Final Assembly Capital Equipment:

OPERATION	NOMENCLATURE - USE
Fastening	
Pneumatic riveters	Assorted rivet drivers are needed to fasten hat sections, skin and ring frames
Pneumatic drills	Assorted drills are required to make fastener holes
Finishing insulation	
Turntable 70-ft diameter	This is needed during insulation application and to rotate the stage for painting
Paint spray equipment	Needed to hand paint the stage skin and hat sections
Foam spray equipment	To apply foam insulation to the stage
Handling	
Crane	A 30-ton overhead bridge crane with a 40-ft clearance is required for handling the injection stage

5.3.4.8 Injection Stage Facilities

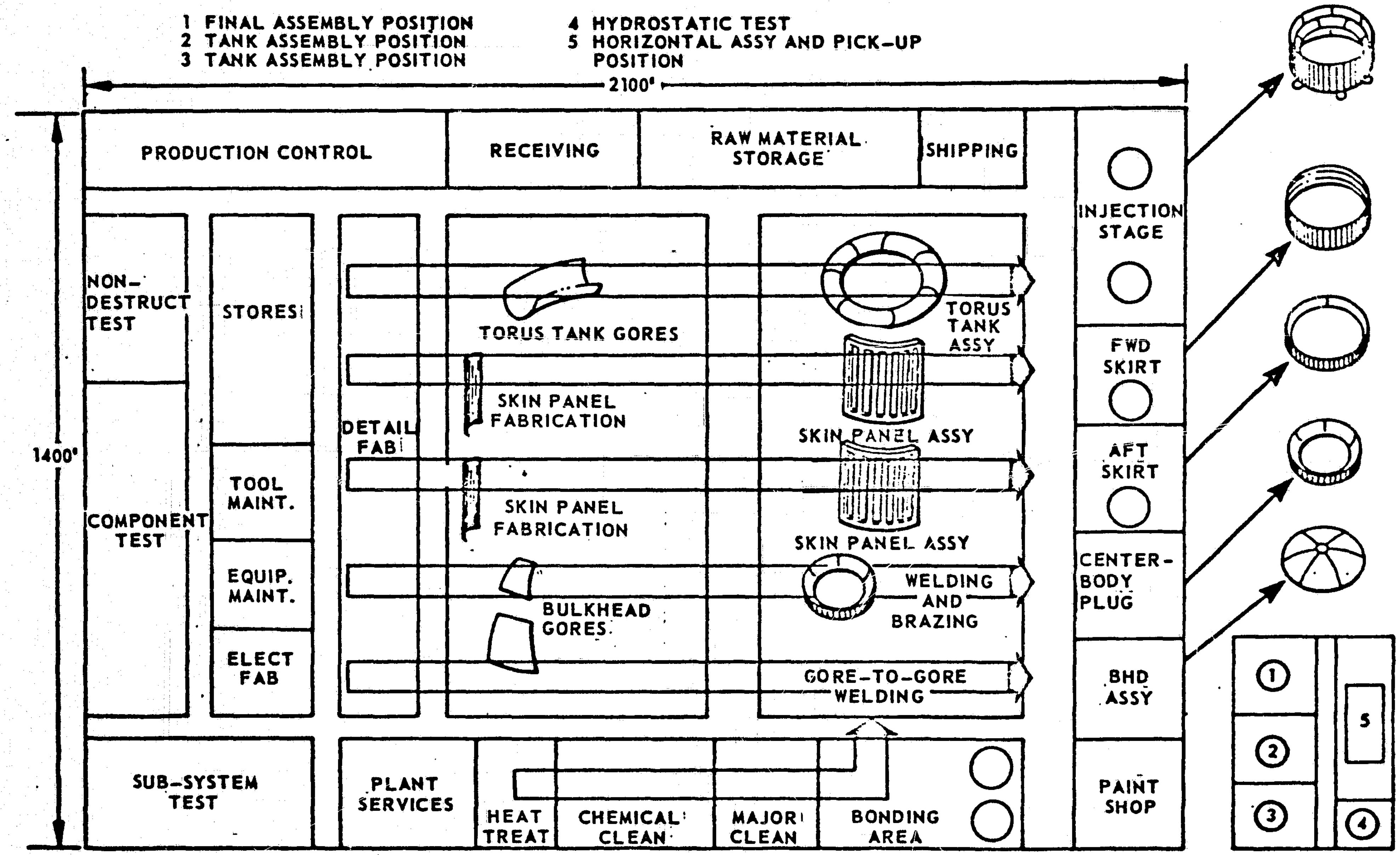
Total maintenance of the manufacturing facility, shown on Figure 5.3.4.8-1, recurring cost as given in Tables 5.3.4.8-I and 5.3.4.8-II on an annual basis for the AMLLV, includes the following:

a. Craft labor maintenance and material;
b. Transportation and handling;
c. Janitorial service;
d. Coordination;
e. Equipment management;
f. Facilities planning;
g. Equipment and plant engineering support;
h. Facilities management.

The maintenance costs were arrived at by dollar/sq. ft./year on scaled actuals of similar programs. On this basis, the maintenance costs were scaled down or up from actual maintenance costs of existing similar Boeing Company facilities maintenance cost, or actual maintenance cost of NASA-sponsored Boeing R&D contracts. The estimates of facility and capital equipment for stage manufacture were developed with the understanding that both the main and injection stages would be produced and assembled in the same facility. In order to arrive at the costs chargeable to the main stage, the maintenance costs were subdivided as shown in Table 5.3.4.8-III.

Tables 5.3.4.8-I and 5.3.4.8-II also give combined costs for the AMLLV and MLLV main and injection stage facilities. Table 5.3.4.8-III breaks these totals down so that the costs of main and injection stage facilities are separately presented.

Similar estimates were prepared for the half-size MLLV. The maintenance costs of the MLLV manufacturing facility are shown in Tables 5.3.4.8-IV and 5.3.4.8-V. The individual estimates of the facility and capital equipment for the MLLV is shown in Table 5.3.4.8-VI, separating main stage facility costs from injection stage facility costs.



NOTE: This layout based upon conceptual layout developed by Huntsville Facilities Organization.

FIGURE 5.3.4.8-1 CORE AND INJECTION STAGE MANUFACTURING FACILITY

TABLE 5.3.4.8-I AMLLV MAIN AND INJECTION STAGE MANUFACTURING BUILDING, NONRECURRING EQUIPMENT AND RECURRING MAINTENANCE

AREA	SQ. FT.	$/SQ. FT. B&M	TOTAL B&M	EQUIPMENT	$/SQ. FT. EQUIP.
Bldg. Shell Low Bay	2,700,000	$ 20.00	$ 54,000,000	$	$
Bldg. Shell High Bay	250,000	100.00	25,000,000		
Skin & core Fab.	320,000	15.00	4,800,000	12,800,000	40.00
Rework and Modification	150,000	10.00	1,500,000	6,000,000	40.00
Chemical Clean	67,500	40.00	2,700,000	4,725,000	70.00
Major Clean	22,500	15.00	337,500	1,125,000	50.00
Minor Assembly	500,000	10.00	5,000,000	4,500,000	9.00
Major Assembly	250,000	10.00	2,500,000	2,500,000	10.00
Major Point	45,000	10.00	450,000	675,000	15.00
Elect./ Electronic	50,000	10.00	500,000	750,000	15.00
Horizontal Instl.	50,000	4.00	200,000	300,000	6.00
Component Test	180,000	25.00	4,500,000	12,600,000	70.00
Subsystem Test	70,000	25.00	1,750,000	1,750,000	25.00
Production Control	100,000	12.00	1,200,000	5,000,000	50.00
Nondestruct Test	25,500	25.00	562,500	450,000	20.00
Measurement Control	15,00	30.00	450,000	375,000	25.00
Mfg. Dev. Lab	15,000	10.00	150,000	1,050,000	70.00
Equipment Maintenance	40,000	1.50	60,000	600,000	15.00
Plant Services	40,000	15.00	600,000	120,000	3.00
Mock Up	40,000	2.50	100,000	5,000	.125
Receiving and Inspection	60,000	2.00	120,000	180,000	3.00
Shipping	37,500	2.00	75,000	50,000	1.35
Whse. & Stores	450,000	1.50	675,000	900,000	2.00
Support Facilities	500,000	1.50	750,000	---	
TOTAL COSTS (AMLLV)			$107,980,000	$56,255,000	

Includes primary utilities, heat, air conditioning

RECURRING MAINTENANCE/YR. BLDG.	EQUIP.
$6,174,000	$2,646,000

TABLE 5.3.4.8-II AMLLV MAIN AND INJECTION STAGE MANUFACTURING SUPPORT AREAS

AREA	SQ. FT.	$/SQ. FT. B&M	NONRECURRING TOTAL B&M	NONRECURRING EQUIPMENT	$/SQ. FT. EQUIP.	RECURRING MAINTENANCE/YR. BLDG.	RECURRING MAINTENANCE/YR. EQUIP.
Vertical Assy. Building	87,500	$ 220.00	$19,250,000	$6,125,000	$70.00	$ 182,000	$ 78,000
Post Mfg. & Stage Test	50,000	120.00	6,000,000	400,000	8.00	100,000	50,000
Office	650,000	27.50	17,875,000	2,115,000	3.25	1,460,000	165,000
Totals			$43,125,000	$8,640,000		$1,742,000	$293,000

TABLE 5.3.4.8-III AMLLV MANUFACTURING FACILITY AND MAINTENANCE COST

Nonrecurring Costs - Manufacturing Building	Total B&M	Total Equipment
Main Stage	$ 80,980,000	$ 42,155,000
Injection Stage	27,000,000	14,100,000
Total	$107,980,000	$ 56,255,000

Nonrecurring Costs - Manufacturing Support Areas	Total B&M	Total Equipment
Main Stage	$ 32,344,000	$ 6,480,000
Injection Stage	10,781,000	2,160,000
Total	$ 43,125,000	$ 8,640,000

Recurring Costs - Manufacturing Building Maintenance		
Main Stage	$ 4,634,000	$ 1,984,000
Injection Stage	1,540,000	662,000
Total	$ 6,174,000	$ 2,646,000

Recurring Costs - Manufacturing Support Areas Maintenance	Total B&M	Total Equipment
Main Stage	$ 1,307,000	$ 219,000
Injection Stage	435,000	74,000
Total	$ 1,742,000	$ 293,000

TABLE 5.3.4.8-IV MLLV MAIN AND INJECTION STAGE MANUFACTURING BUILDING, EQUIPMENT AND MAINTENANCE

AREA	SQ. FT.	$/SQ. FT. B&M	TOTAL B&M	EQUIPMENT
Bldg. Shell Low Bay	2,700,000	$ 20.00	$54,000,000	$
Bldg. Shell High Bay	200,000	100.00	20,000,000	
Skin & Core Fab.	250,000	15.00	3,750,000	10,500,000
Rework and Modification	120,000	10.00	1,200,000	6,000,000
Chemical Clean	60,000	40.00	2,400,000	4,725,000
Major Clean	20,000	15.00	300,000	1,125,000
Minor Assembly	400,000	10.00	4,000,000	4,500,000
Major Assembly	200,000	10.00	2,000,000	2,500,000
Major Paint	35,000	10.00	350,000	675,000
Electrical/ Electronic	40,000	10.00	400,000	750,000
Horizontal Instl.	40,000	4.00	160,000	300,000
Component Test	150,000	25.00	3,750,000	12,600,000
Subsystem Test	60,000	25.00	1,500,000	1,750,000
Production Control	100,000	12.00	1,200,000	5,000,000
Nondestruct Test	23,225	25.00	505,500	450,000
Measurement Control	15,000	30.00	450,000	375,000
Mfg. Dev. Lab	15,000	10.00	150,000	1,050,000
Equipment Maintenance	40,000	1.50	60,000	600,000
Plant Services	40,000	15.00	600,000	120,000
Mock Up	40,000	2.50	100,000	5,000
Receiving and Inspection	60,000	2.00	120,000	180,000
Shipping	37,500	2.00	75,000	50,000
Whse. & Stores	450,000	1.50	675,000	900,000
Support Facilities	500,000	1.50	750,000	--
TOTAL COSTS (MLLV)			$98,500,000	$53,755,000

Includes primary utilities, heat, air conditioning

RECURRING MAINTENANCE/YR.

BLDG.	EQUIP.
$5,880,000	$2,520,000

TABLE 5.3.4.8-V MLLV MAIN AND INJECTION STAGE MANUFACTURING SUPPORT AREAS

AREA	NONRECURRING			RECURRING	
	TOTAL B&M	EQUIPMENT	$/SQ. FT. EQUIP.	MAINTENANCE/YR. BLDG.	MAINTENANCE/YR. EQUIP.
Vertical Assy. Building	$15,400,000	$5,525,000	$87.90	$ 147,000	$ 63,000
Post Mfg. & Stage Test	4,800,000	400,000	10.00	85,000	50,000
Office	17,875,000	2,115,000	3.25	1,460,000	165,000
	$38,075,000	$8,040,000		$1,692,000	$578,000

TABLE 5.3.4.8-VI MLLV MANUFACTURING FACILITY AND MAINTENANCE COST

Nonrecurring Costs - Manufacturing Building		
	Total B&M	Total Equipment
Main Stage	$ 73,875,000	$ 40,316,000
Injection Stage	24,625,000	13,439,000
Total	$ 98,500,000	$ 53,755,000
Nonrecurring Costs - Manufacturing Support Areas		
	Total B&M	Total Equipment
Main Stage	$ 28,556,000	$ 6,030,000
Injection Stage	9,519,000	2,010,000
Total	$ 38,075,000	$ 8,040,000
Recurring Costs - Manufacturing Building Maintenance		
	Total B&M	Total Equipment
Main Stage	$ 4,410,000	$ 1,890,000
Injection Stage	1,470,000	630,000
Total	$ 5,880,000	$ 2,520,000
Recurring Costs - Manufacturing Support Areas Maintenance		
	Total B&M	Total Equipment
Main Stage	$ 1,269,000	$ 208,000
Injection Stage	423,000	70,000
Total	$ 1,692,000	$ 278,000

5.4 SOLID ROCKET MOTOR (SRM) STAGE MANUFACTURING PLAN

The MLLV configurations employ as many as eight, and the AMLLV as many as twelve 260-inch diameter solid propellant rocket motor stages. The SRM stages for the MLLV each contain 2.9 million pounds of solid propellant [the AMLLV SRM stages each contain 3.8 million pounds of solid propellant]. Both SRM stages employ a flexible nozzle thrust vector control system. Components of the solid rocket motors consist of a case, propellant, nozzle, ignition system, thrust vector control system and a destruct system. To convert the solid motor to a stage, on-board power sources, flight instrumentation, forward and aft attachment fittings, a nose cone and a separation system must be added. For this study, it was assumed that the forward and aft attachment structures and the solid motor nose cone will be fabricated by a contractor at the Michoud facility. All other solid motor and solid motor stage components will be procured and/or supplied by the SRM contractor. Figure 5.4.0.0-1 illustrates the SRM stage components.

When the 260-inch SRM stages are used in either the AMLLV or MLLV configurations, they will be mounted equidistant in a circle, and parallel to the stage centerline.

The SRM stages will be started simultaneously at liftoff, and will be staged simultaneously after the net acceleration of each and all of the strap-on stages is less than that of the core vehicle. (This applies for all launches employing strap-ons except where only two strap-ons are used. Then a parallel launch mode is used. The SRM's are staged when both SRM's operating pressure drops to ten percent of maximum pressure.)

5.4.1 SRM Stage Manufacturing Plan

The SRM stage manufacturing plan is applicable to the SRM stage for both the AMLLV and the MLLV. The schedule for each will be identical. The only differences between the SRM for the different vehicle configurations will be the Resources as shown in Section 5.4.2.

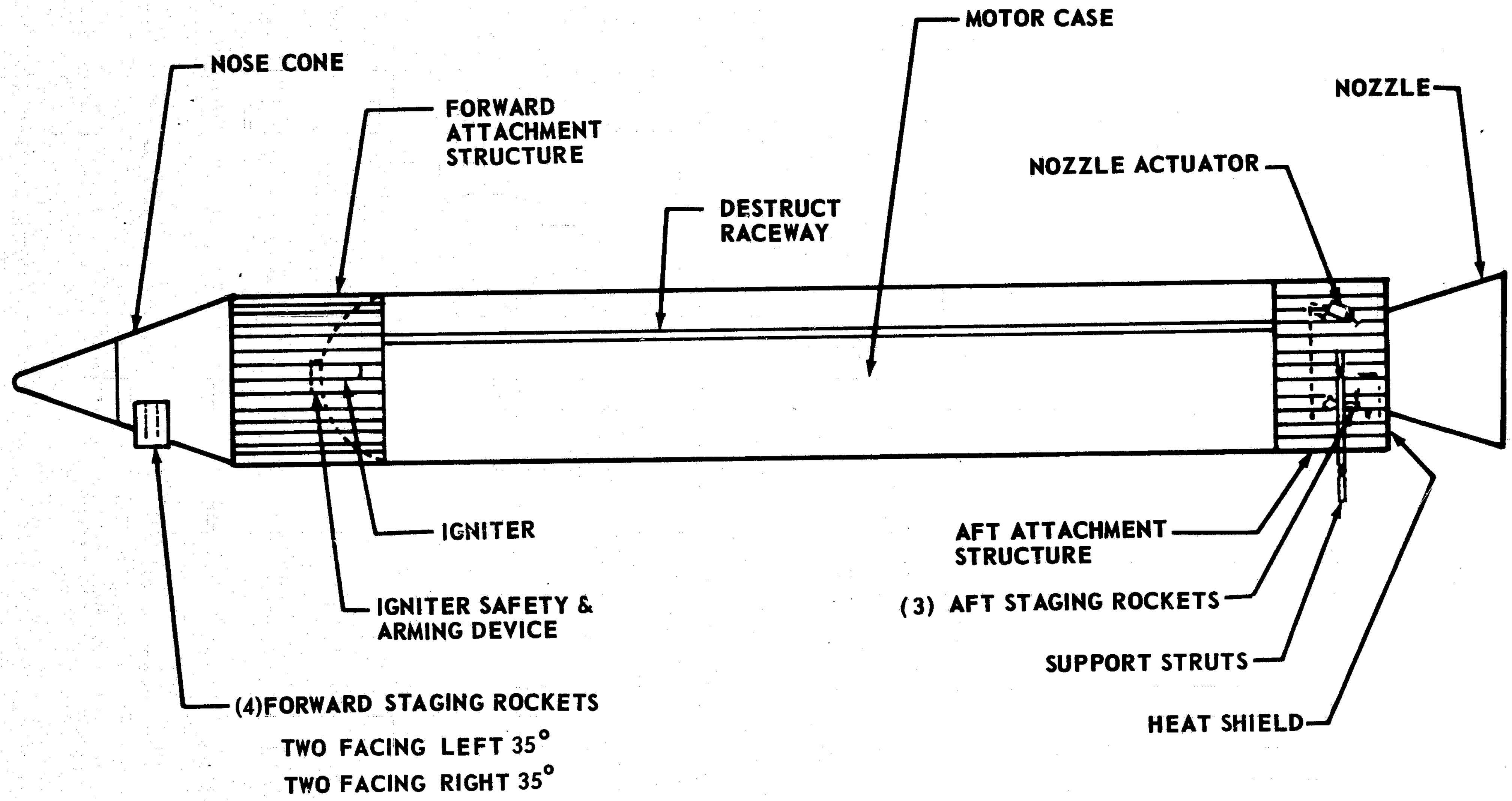


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FIGURE 5.4.0.0-1 260-INCH MOTOR COMPONENTS

5.4.1.1 Motor Component Fabrication

The solid propellant motor design proposed for the AMLLV and MLLV configurations are based on the same component designs as used for motors fabricated and static test fired in the 260-inch diameter Motor Feasibility Demonstration Program. Major motor components will be fabricated by subcontractors using the materials and fabrication processes which have been demonstrated.

Shipyard facilities are particularly suited to fabrication of the motor chamber. Equipment normally used in ship building is usable for the plate cutting, forming, machining and welding operations required. Additionally, and of particular importance, the waterside location enables loading each complete chamber directly on a barge for transport to the motor processing facility. Fabrication of the two 260-inch diameter chambers for the feasibility demonstration program was accomplished by Sun Shipbuilding and Dry Dock Company at their facilities in Chester, Pennsylvania.

The chambers will be fabricated from 18 percent maraged steel with a minimum yield strength of 200,000 psi. Sections of the case cylindrical section will be shear-spun. This will reduce the need for longitudinal welds. With horizontal welds only, one-half the stress is experienced and, therefore there is no need for weld lands or increased wall thickness. The cylindrical sections will be shear-spun as a series of rings, termed "courses". Figure 5.4.1.1-1 illustrates a cylindrical course 260-inches in diameter. The cylindrical courses will be assembled on a horizontal rotating fixture and joined by girth welds to form a subassembly.

The chamber hemispherical heads will be fabricated from maraging steel with a minimum yield strength of 200,000 psi. The hemispherical heads will be shear-spun. The opening for the igniter boss in the head-end dome will be 28-inches in diameter. The opening for attachment of the nozzle on the aft-end dome will be 180-inches in diameter. The igniter boss and the nozzle attachment rings will be fabricated from forgings. A forged Y-ring will be welded to the ends of the hemispherical domes to provide the transition to the cylindrical section and the skirts. A short forward and aft skirt will be shear-spun and welded to the Y-ring.

After welding of forward and aft-head subassemblies to the cylindrical section, the complete chamber will be subjected to maraging heat treatment. A maraging cycle of four to eight hours with temperature maintained at 800 to 900°F is required. Chamber attachment flange final machining will be completed after maraging, and the assembly will then be subjected to hydrostatic proof-pressure test. The forward and aft motor handling rings will be installed and the motor chamber will be loaded on the barge.

Nozzle ablative components will be fabricated of carbon and silica tapes impregnated with phenolic resin. The initial step in fabrication will consist of tape wrapping

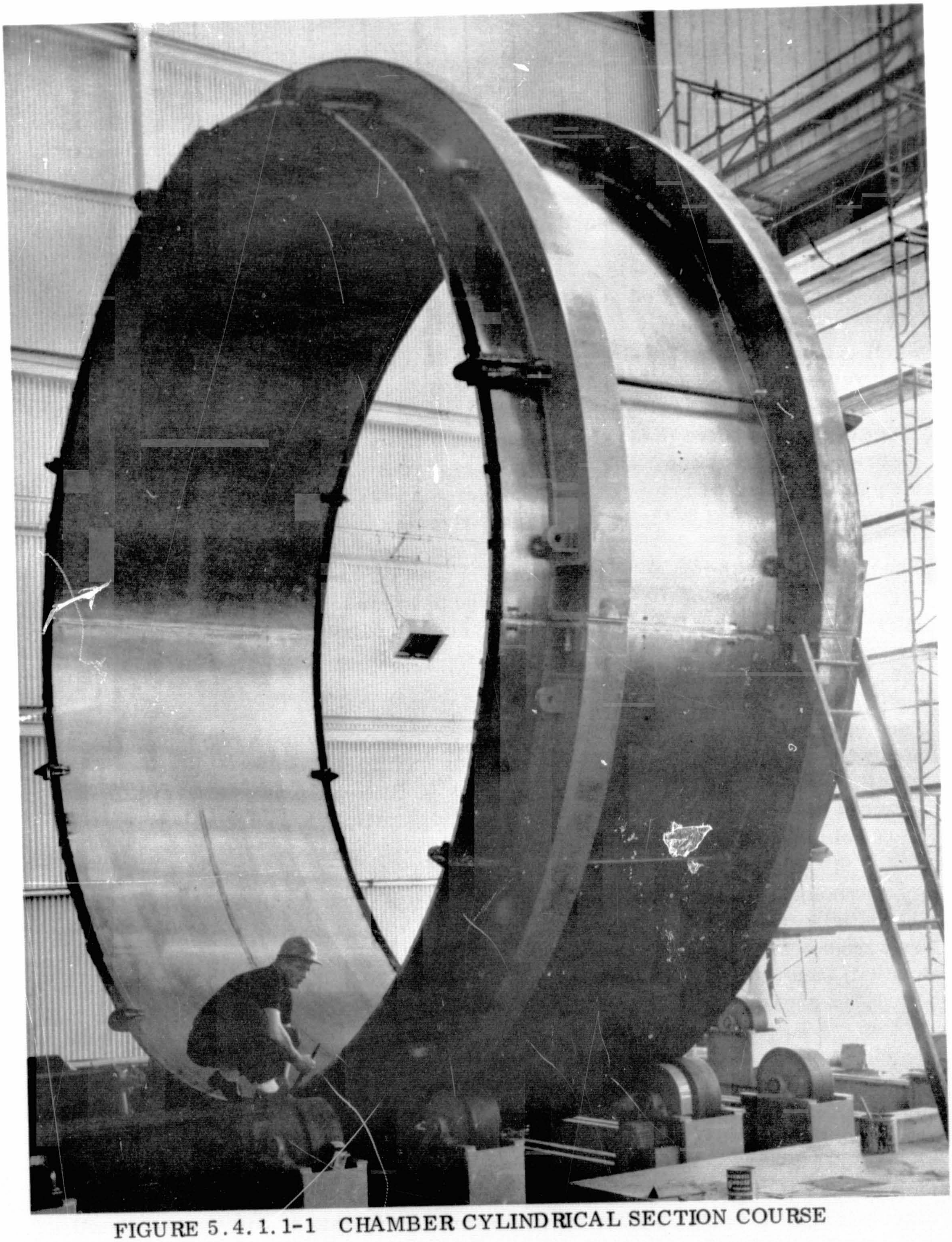

FIGURE 5.4.1.1-1 CHAMBER CYLINDRICAL SECTION COURSE

5.4.1.1 (Continued)

with roller debulking using inside-contour mandrels. Figure 5.4.1.1-2 shows a typical tape wrapping operation. The tape-wrapped carbon or silica billet will be subjected to a preform debulking cycle at 1000 psig and 175° F. A parallel-to-surface silica overwrap will then be applied and the composite billet final cured in a hydroclave cycle at 1000 psig and 300° F. The cured ablative component will then be machine finished to mate with the structural shell. The fabricated sequence for the throat insert as summarized on Figure 5.4.1.1-3 is typical for all ablative components.

The nozzle shell will be fabricated of 18 percent nickel maraging steel ring-rolled forgings, joined by girth welding in the same manner as chamber components. The shell will be final machined after maraging heat treatment. Ablative components will be bonded to the structural shell with epoxy adhesive, Figure 5.4.1.1-4.)

The exit cone ablative liner will be fabricated in the same manner as the nozzle inserts, except that autoclave or oven-cure cycles will be used. The exit cone support structure will be of built-up honeycomb construction with facings and core successively bonded to the liner with epoxy resin.

The chamber insulation will consist of precured rubber sheet stock and molded segments. Conventional procedures will be used for forming of components to mate the chamber configuration and for curing in autoclave cycles.

5.4.1.2 Motor Processing

For costing purposes, it was assumed that the motors would be processed at Aerojet-General Corporation's Dade Division facility located approximately 35 miles southwest of Miami, Florida. This facility was activated in 1963 and provides the capability to perform all operations required for production of large solid propellant rocket motors.

The sequence of basic motor processing operations is shown in Figure 5.4.1.2-1. The initial series of inert processing operations will include preparation of chamber surfaces for bonding of insulation. The premolded rubber insulation components will then be bonded to the chamber with epoxy resin adhesives. Figure 5.4.1.2-2 shows installation of rubber sheet stock in the chamber cylindrical section. A liner material which serves to bond the propellant grain to the insulation chamber will be hand applied to finished insulation surfaces.

In the next series of operations, the motor will be loaded with propellant. The insulated and lined chamber will be assembled with the forward attachment structure and the forward stage handling ring and installed in the Cast-Cure and Test (CCT) facility caisson, which is about 50 feet in diameter and 150 feet deep. The casting core, which will serve to form the grain bore configuration, will then be installed

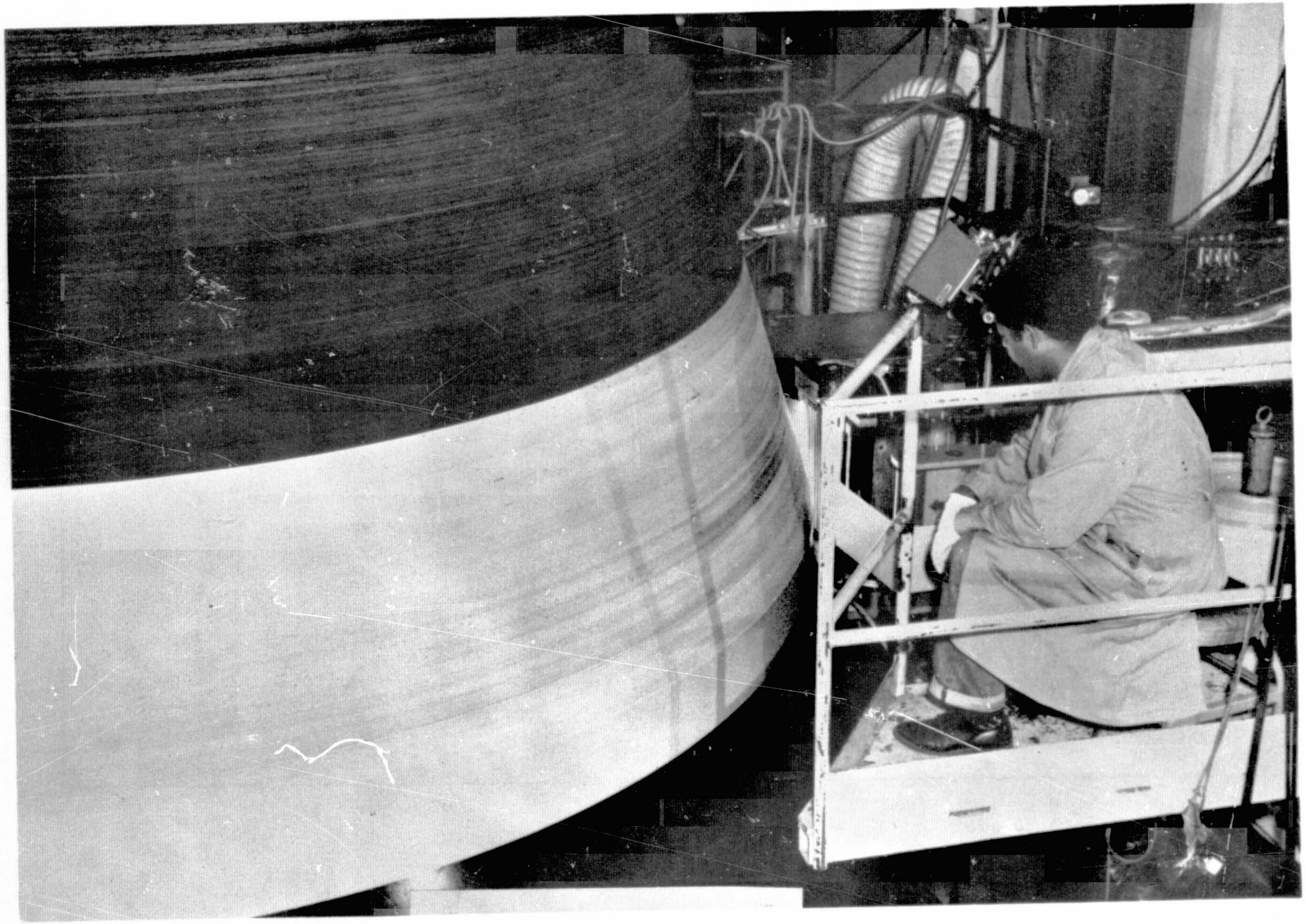

FIGURE 5.4.1.1-2 ABLATIVE COMPONENT TAPE WRAPPING

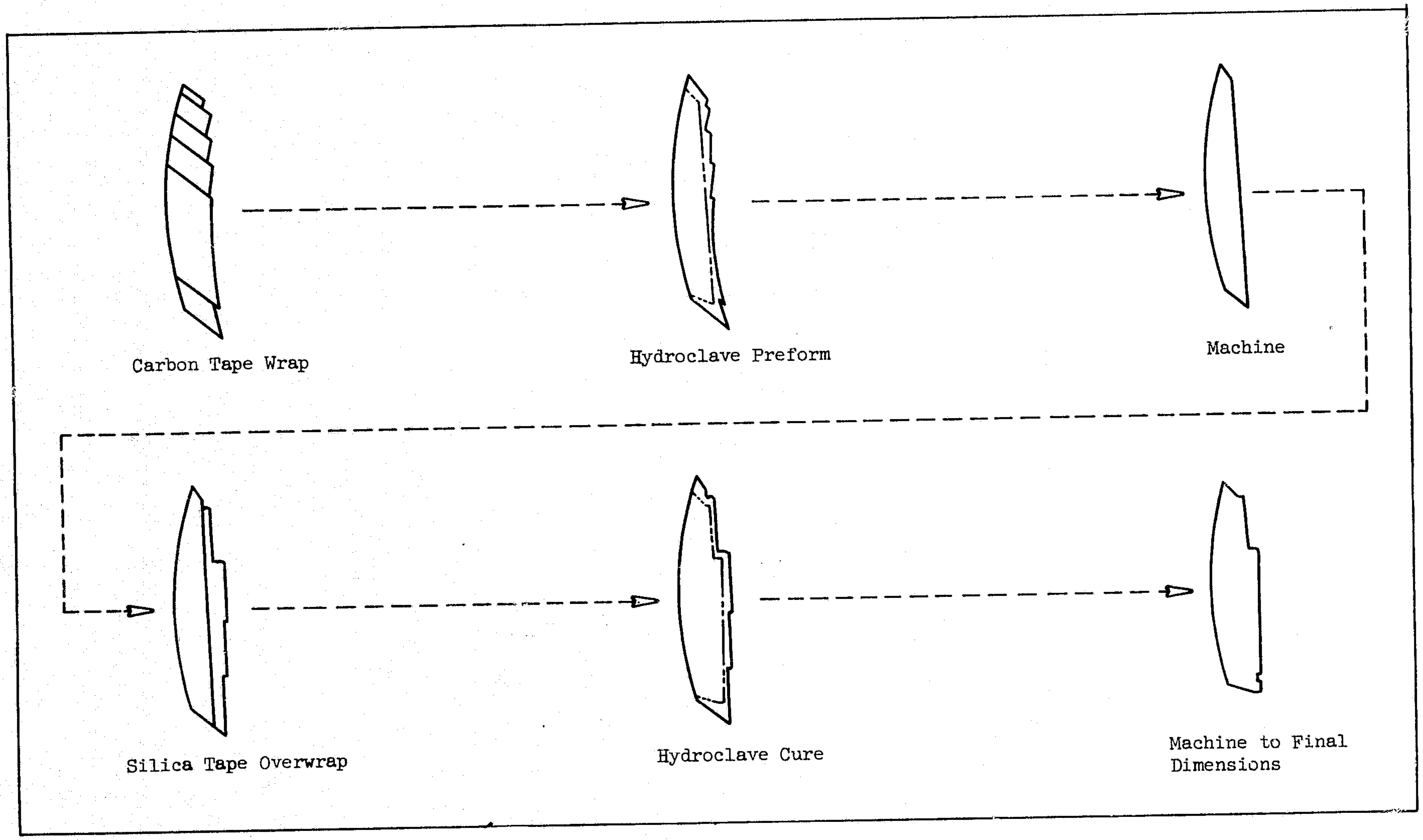

FIGURE 5.4.1.1-3 THROAT INSERT FABRICATION

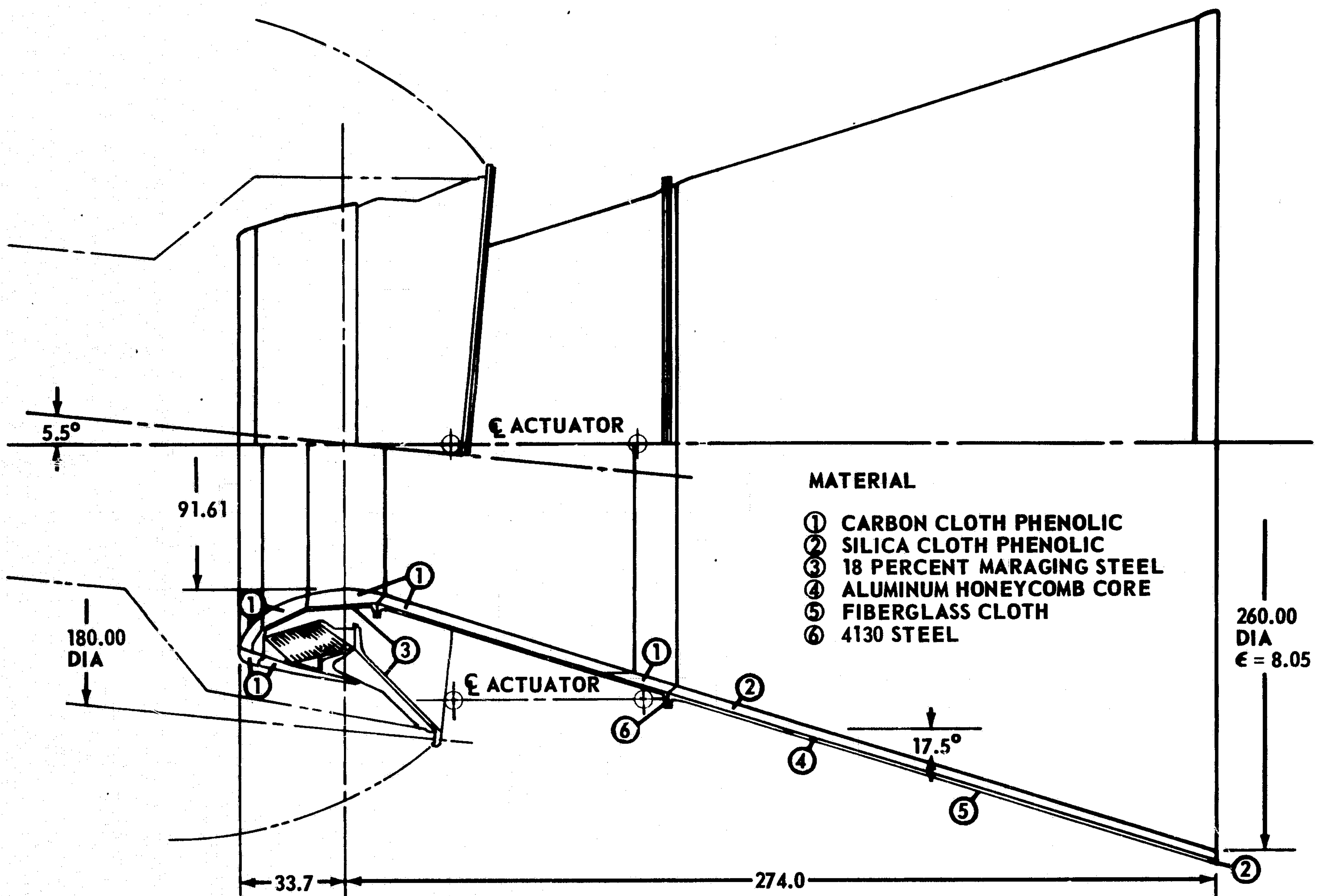

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FIGURE 5.4.1.1-4 NOZZLE ASSEMBLY 260-INCH MOTOR

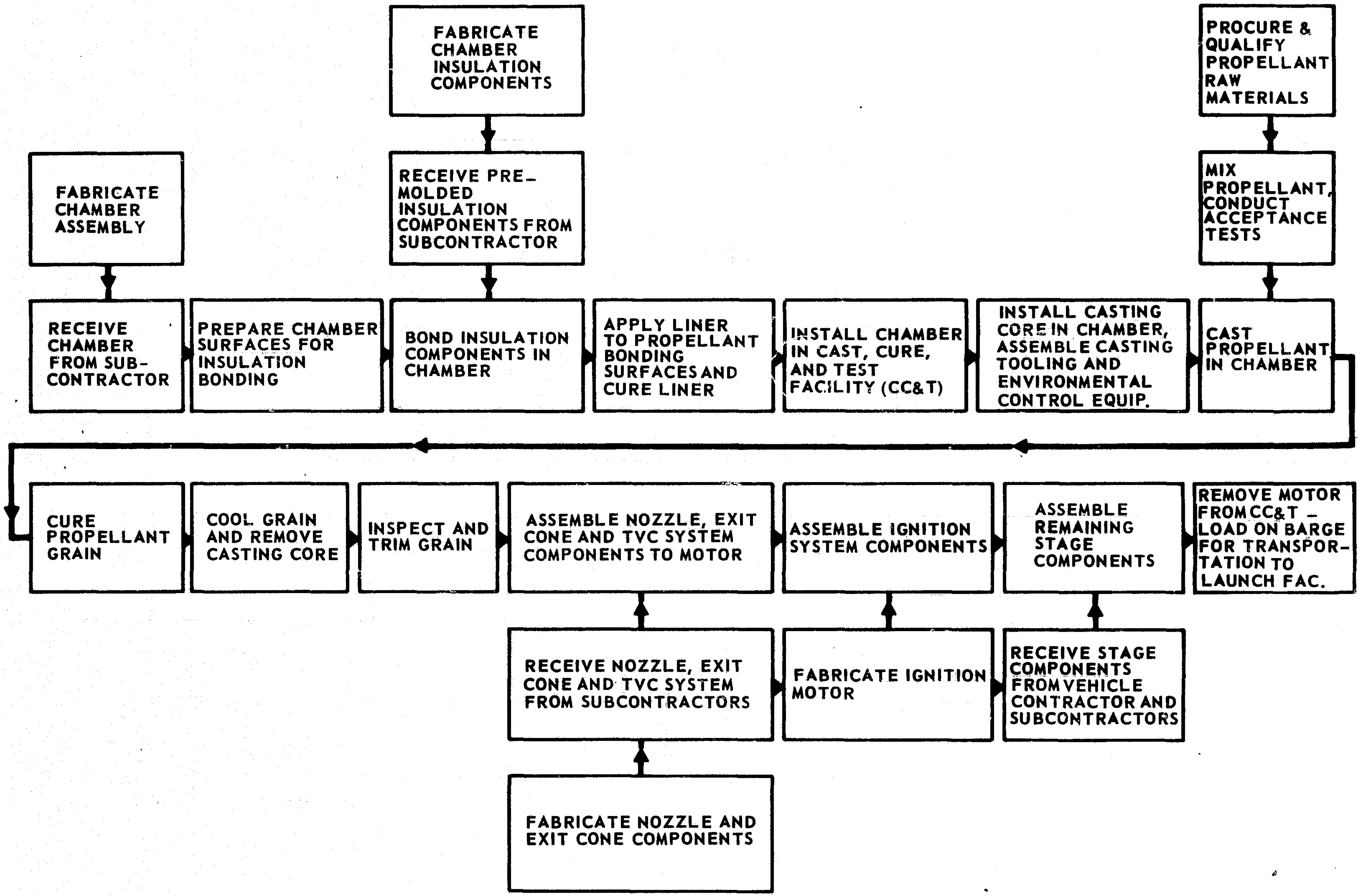


FIGURE 5.4.1.2-1 260-INCH DIAMETER MOTOR MANUFACTURING PROCESS

FIGURE 5.4.1.2-2 INSTALLATION OF CHAMBER INSULATION

5.4.1.2 (Continued)

inside the chamber. After assembly of the remaining casting tooling, a movable casting building will be secured in position over the caisson and environmental control equipment will be placed in operation to maintain propellant temperature during casting and curing.

Major operations in the production of propellant and motor loading are discussed in the following paragraphs.

Oxidizer Preparation — To achieve the oxidizer particle size required in the final propellant grain, the oxidizer may be ground in hammer mills. Quantities of the ground material will then be measured, mixed, and blended to achieve a homogeneous mixture of oxidizer having the requisite particle size distribution.

Fuel Preparation — Ingredients for the fuel premix will be dispensed into mixing tanks in metered quantities. After mixing and acceptance, measured quantities of the final premix will be dispensed into containers for transport to propellant mixing stations.

Propellant Mixing — Both batch mixing and continuous mixing systems are used at the Dade Division facility. In the batch process, the premix, curative, and oxidizer are dispensed into the mixer bowl in measured quantities to produce a total batch weight of about 5,500 pounds. The mixer bowl is locked in position on the mixing head and a vacuum mix cycle is conducted. After mixing, the mixer bowl is removed from the mixer head, sealed, and used as the transport container to deliver the propellant to the motor loading site. In the continuous mixer system, the separate ingredients are continuously dispensed at metered rates into a screw type mixer. From the mixer, the propellant moves through a deaerator and is then dispensed into transport pots for delivery to the motor loading site.

Acceptance Test — Samples will be removed from each container of mixed propellant prior to transport from the mixing station to the motor loading site. The samples will be taken to the Quality Control Laboratory for chemical analysis and liquid strand burning rate determinations. Only when these measurements are within specified limits, will the propellant be accepted for casting into the motor.

5.4.1.2 (Continued)

Propellant Casting — The propellant container will then be moved to the casting buildings where a diaphragm will be installed, and the container sealed and positioned on a casting stand. A casting hose, extending to the surface of propellant in the motor, will be attached to a valve at the bottom of the container. The top of the container above the diaphragm will be pressurized with nitrogen and the valve then opened so that propellant can be forced from the container out through the casting hose. Figure 5.4.1.2-3 shows a propellant container in position for casting.

Upon completion of casting, a propellant cure cycle will be conducted with the grain maintained at about 135 degrees F. When cure is completed, the grain will be cooled to ambient temperature and the casting core removed. A final inspection of the grain will be conducted, and the aft-end surface trimmed to final configuration. The loaded chamber will then be ready for mating of the nozzle, exit cone, TVC system, ignition system, and remaining stage components except for the nose cone. When the assembly is completed, the motor will be removed from the caisson, loaded on a barge for transport to the launch facility, then the nose cone will be assembled to the SRM stage.

5.4.1.3 Stage Component Manufacture

The strap-on stage components will consist of an onboard power source, a flight instrumentation system, a separation system, solid motor attachment fixtures and a solid motor nose cone, Figure 5.4.1.3-1. The onboard power system, flight instrumentation and the separation system will be fabricated or procured by the solid-motor contractor and installed on the solid motor at the fabrication site. The forward and aft attachment fittings and the nose cone will be fabricated and shipped to the solid motor fabrication site for assembly to the solid motor stage. A description of SRM interface hardware is contained in the following paragraphs.

Forward Attachment Structure -- The SRM forward attachment structure will be a cylinder, 260-inches in diameter constructed of HY-140 steel. It will be of a skin-stringer-frame construction. The forward skin will consist of fourteen sections welded together to form a 260-inch diameter cylinder. One of the sections will incorporate a forged ignition fitting and igniter safety and arming device fitting. The skin sections will be delivered in the heat treated condition, plasma arc rough trimmed, and rolled to the desired curvature. Stress relieving may be required after rolling. The skin sections will then be placed in a trim fixture and trimmed to the desired size. After trimming, the

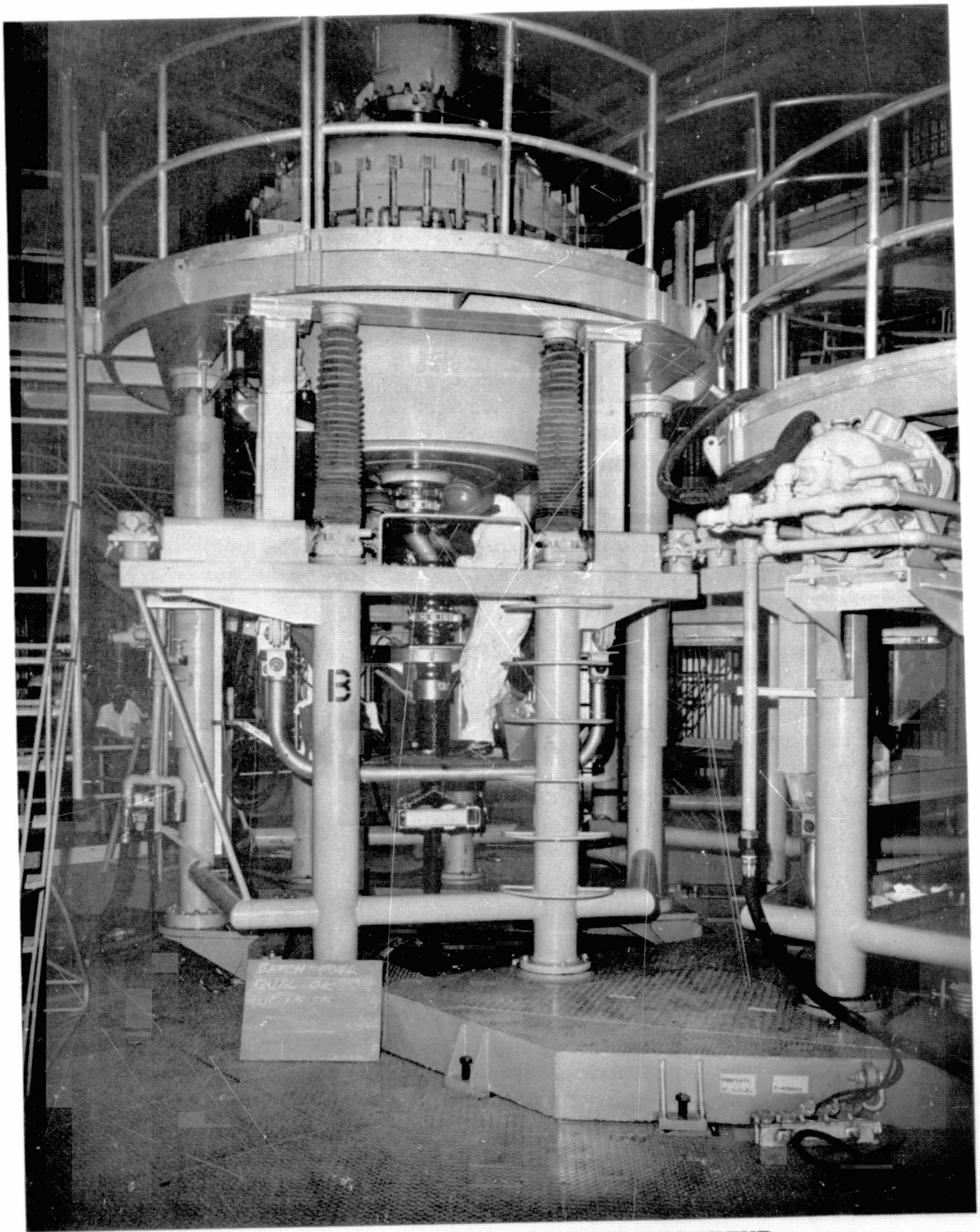
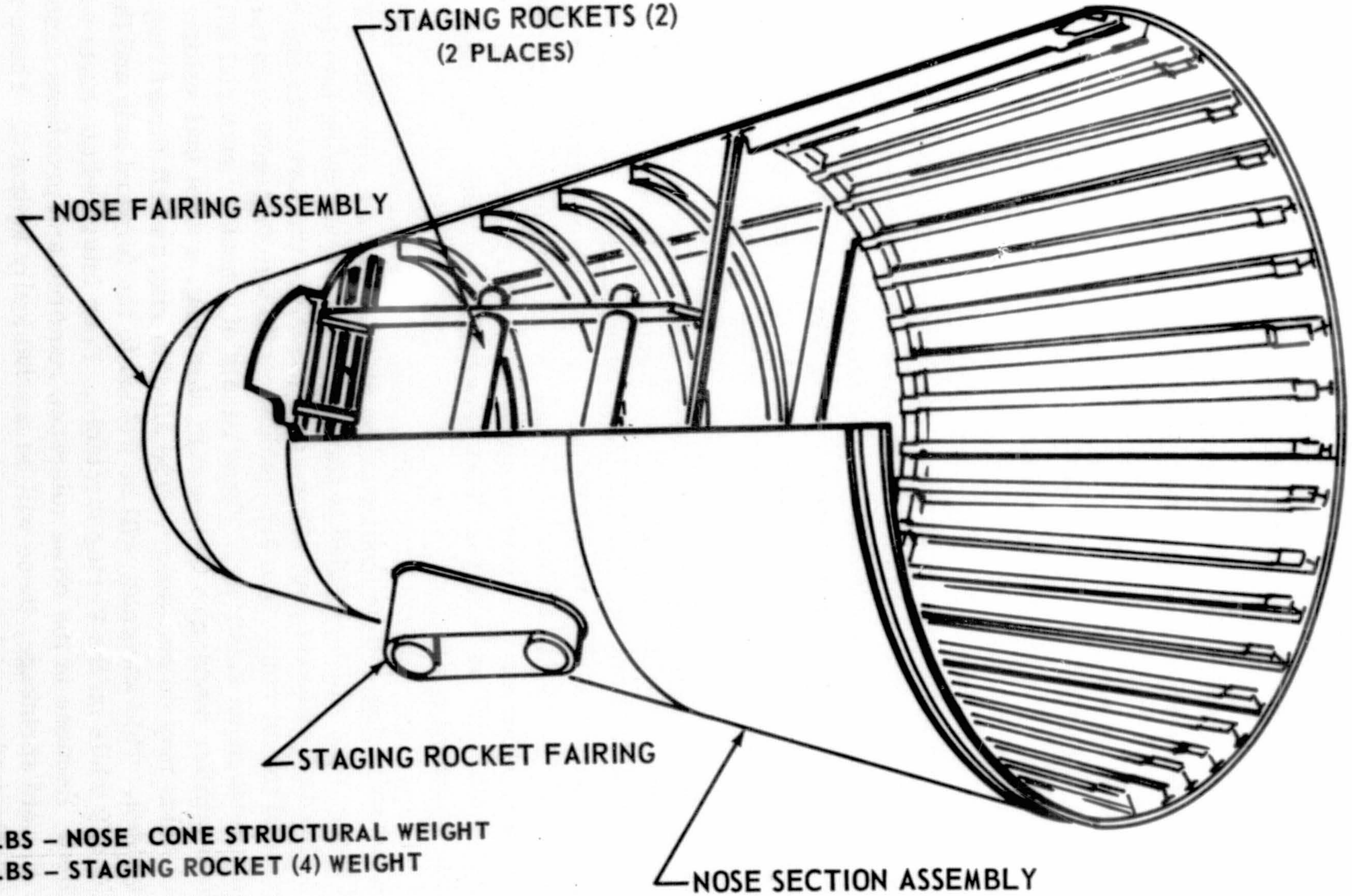


FIGURE 5.4.1.2-2 PROPELLANT CASTING SETUP



2,680 LBS – NOSE CONE STRUCTURAL WEIGHT
2,380 LBS – STAGING ROCKET (4) WEIGHT

5,060 LBS TOTAL WEIGHT

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FIGURE 5.4.1.3-1 SRM NOSE SECTION ASSEMBLY

5.4.1.3 (Continued)

skin sections will be etched and cleaned. They will then be loaded into a weld fixture, along with etched and cleaned shear posts, hand-tack-welded and MIG welded from one side to form a complete ring. The assembly will then be rotated and each succeeding joint welded to complete the forward skin ring. Each weld joint will be inspected for weld integrity.

The SRM thrust (shear) post will be fabricated from HY-140 and will be MIG welded to the forward skin ring. The post will consist of a cross shape 180 inches long by 68 inches wide. The cross vertical leg will taper from approximately 14 inches wide at the end to 22 inches at the intersection of the cross. The horizontal leg will be tapered from six inches at the end of the legs to eight at the cross intersection. To provide additional structural rigidity, web stiffeners will be welded to the cross to prevent buckling. A steel sleeve 20 inches in diameter and 15 inches long will be welded to the cross intersection. A 12-inch circumferential O.D. groove seven inches deep and four inches wide on the SRM steel sleeve provides the mating surface to the core sleeve. Figure 5.4.1.3-2 illustrates the forward attachment structure. After the shear post is welded to the forward skin ring, the structure will be stiffened longitudinally by one-fourth inch by two-inch ribs welded to the one-eighth-inch thick skin every three inches on the external surface.

The forward thrust ring will be welded to the upper surface of the forward skin ring. The forward thrust ring will be fabricated from the section chords into quadrants and trimmed to the proper length. After trimming, the quadrants will be etched and cleaned. They will be positioned in a weld fixture and welded to form a complete ring. Welds will be shaved to contour. Z-section web stiffeners will provide structural rigidity. Whether or not machine finishing will be required depends upon the degree of distortion introduced by welding.

The forward skin ring will be positioned on an adaptor on a turntable. The forward thrust ring will be welded to the forward skin ring using Hawthorne clamps. The forward skin ring will be butt welded to the forward edge of of the forward thrust ring. The skin panel will be welded together to form a short aft monocoque skin ring. These panels of a heavier material will be welded in a similar manner to the forward skin ring, except that welding from both sides may be necessary. The aft skin ring and aft thrust ring will then be welded. This assembly will be welded to the forward skin and thrust ring assembly while on the Y-ring turntable. Four intermediate rings will be installed. Because of the close tolerance required and problems associated with weld shrinkage, these will be mechanically fastened. These rings will be roll formed in quadrants of I-sections somewhat smaller in cross sections than the foregoing rings. The quadrants will be trimmed to size and mechanically fastened in place using a positioning fixture. They will then

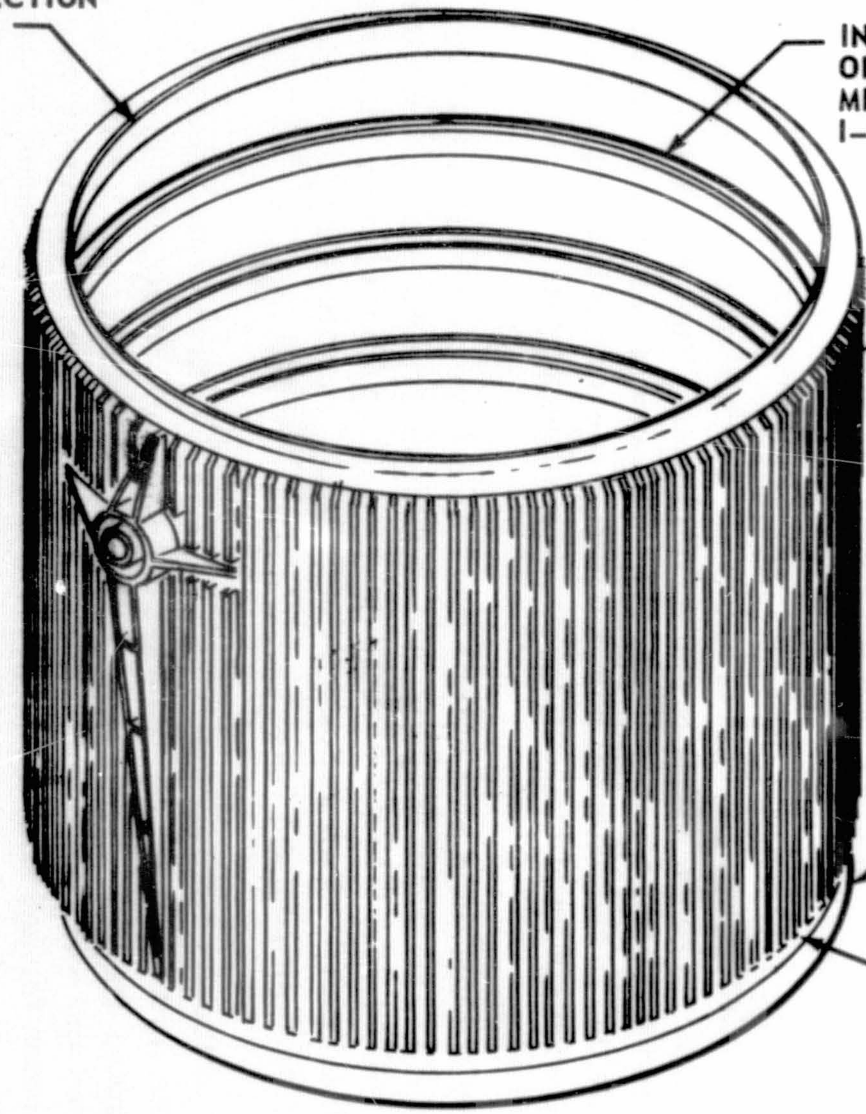

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FIGURE 5.4.1.3-2 SRM FORWARD SKIRT ATTACHMENT STRUCTURE

5.4.1.3 (Continued)

be spliced with doublers across the ribs and inboard flanges.

Because of the distortion inherent in welding, it will be preferable to weld the external longitudinal stringers to the forward skin ring at this stage of assembly where the skin is rigidly held in place. Minor modification to the skin ring welding fixture will render it usable for longitudinal stiffener welds. Stringer holding devices will be necessary - the degree of sophistication upon the tolerances specified.

The structure will then be painted and shipped to the solid-motor contractor's facility. Table 5.4.1.3-I lists the major tools required to fabricate the forward attachment structure.

Solid Motor Aft Attachment Structure — The aft attachment structure will be cylindrical in shape with a height of 120 inches, Figure 5.4.1.3-3. It will be an HY-140 steel structure, with longitudinal stringers similar to the attach structure welded to the external skin surface. The skin will be supported on the inside with six reinforcing rings and two support posts.

The cylindrical skin ring will be fabricated from twenty skin sections five feet wide, 120 inches long and one-eighth-inch thick. Using tapered rollers, they will be rolled to the desired curvature, rough trimmed, heat treated and finish trimmed. Two of these skins will incorporate fairings to house the lower SRM staging rockets.

Four of the six reinforcing rings will have the same cross section and will be stretch formed quadrants from I-Beams approximately 2 by 3 by .250 inches. The upper ring, however, will be rolled cylindrically into quadrants, etched, cleaned and welded into a complete ring in a fixture. The lower ring will be stretch formed and welded in a similar manner to the upper ring. Welds will then be shaved to contour. Machining may be necessary depending upon the forming accuracy and the degree of weld distortion. The attachment ring will be stretch formed from I-sections, 3 by 6 by .250 inches.

The skin section and support posts will be welded in a holding fixture in a manner similar to the forward attachment structure. Each of the two vertical support posts will be comprised of two welded and machined forgings. The top and bottom edges of the skin ring will be machined to be parallel and to compensate for weld shrinkage by adjusting the diameter to fit the forward and aft rings within the allowable tolerance of the aft attachment structure's length.

TABLE 5.4.1.3-I TOOL LIST - FORWARD ATTACHMENT STRUCTURE

Assembly Fixture

Ring Quadrant Assembly Fixture

Forward Skirt Handling Fixture

Ring Quadrant Handling Fixture

Ring Quadrant Storage Rack

Skin Trim Fixture

Skin Heat Treat Fixture

Hat Section Trim Fixture

Skin Section Assembly Fixture

Skin Handling Fixture

Skin Storage Rack

Compression Post Trim Fixture

Tension Post Trim Fixture

Attach Forging Milling Fixture

Attach Strut Milling Fixture

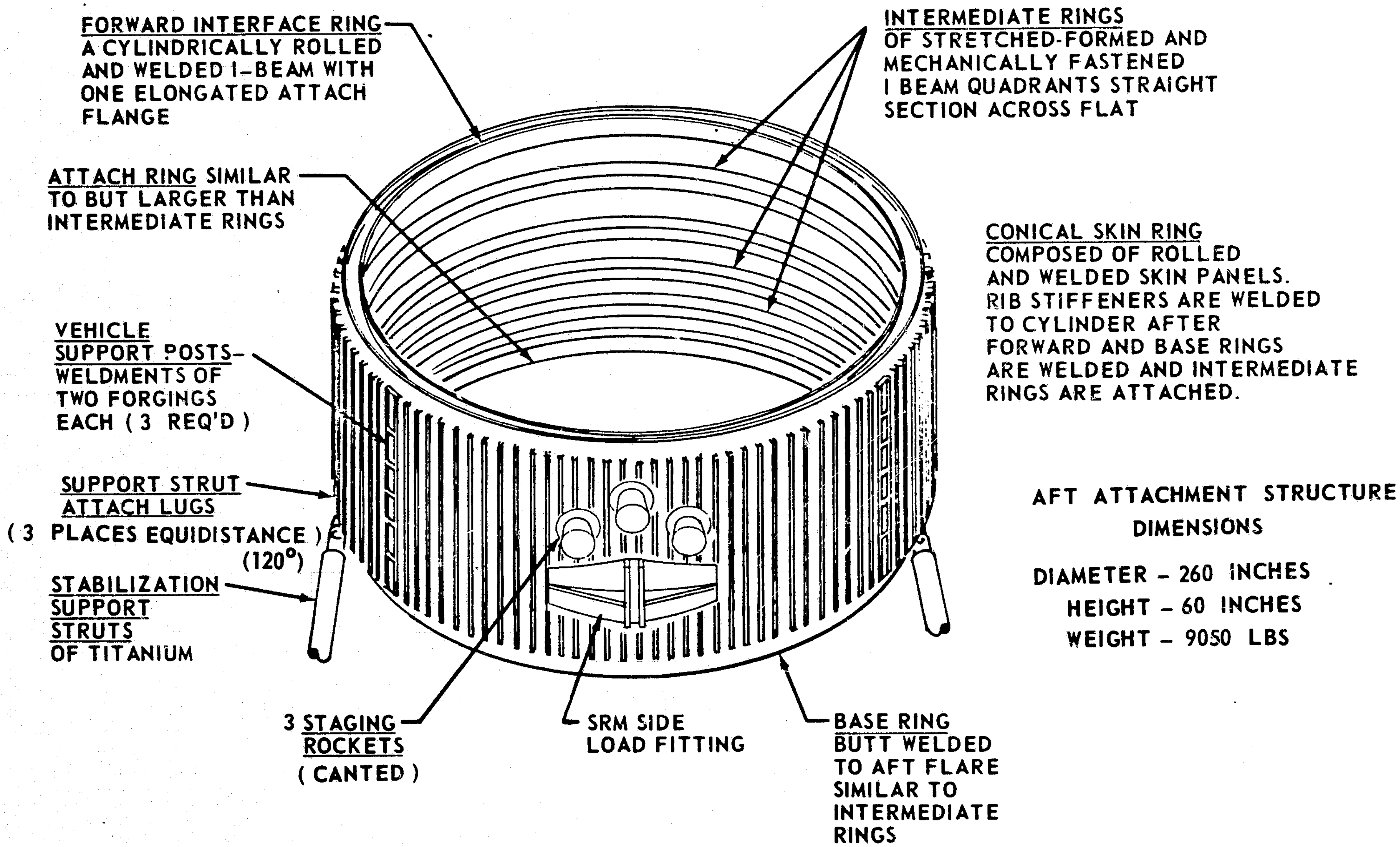

FIGURE 5.4.1.3-3 SRM AFT ATTACHMENT STRUCTURE

5.4.1.3 (Continued)

The reinforcing rings will be attached and the longitudinal stiffeners welded in the same manner as described for the forward attachment structure. The skirt after painting will then be shipped to the solid motor contractor's facility for assembly to the solid motor. Table 5.4.1.3-II lists the major tools required to fabricate the aft skirt.

Solid Motor Aft Attachment Fittings — The aft attachment fittings will consist two tubular support struts and a side load fitting. The tubular support struts will extend between the SRM attach lugs and the attachment fittings mounted on the core stage. The struts and the attachments on the core will be 7075-T6 AL. The SRM fittings will be HY-140 steel. The struts will be approximately 17 feet long. Both ends of the struts will contain spherical bearings. One end will be pinned to the SRM attachment lug; the other end will be pinned to the core lug. An explosive nut, located within the strut, will be used to release the tension bolt. The tension bolt will then release the strut with the SRM stage at SRM burnout. The explosive nut and tension bolt will be located in the neckdown section of the strut at the core stage. Releasing the struts at this location will minimize the inert attachment structure weight carried by the core stage.

The side load-fitting located in the SRM stage will mate with a slip load-fitting welded to the core stage. The slip load-fitting will be fabricated from die forged 7075-T6 AL. The spherical ball mounted in the side load-fitting rides in the channel of the slip load-fitting will permit vertical movement of the SRM stage as it elongates slightly (five inches) during operation.

Solid Motor Nose Cone — The nose cone will be a conical 7075 aluminum alloy structure with a base diameter of 260 inches and a height of 334 inches. The cone will be reinforced on the inside with 40 Z-section stringers and five rings. The skin will consist of two skin ring sections and a nose fairing assembly. The center skin section will also have the staging rocket fairing mechanically fastened to the skin. The staging rocket will be supported by bracketry on the cone interior. The entire exterior of the cone will be covered with an ablative coating. The lower skin section is .060 inches thick. They are trimmed in the flat pattern and riveted to the reinforcing rings in an assembly fixture. The skins are 150 inches long and 36 inches wide at the base. Twenty-three skins are required per section. The center section is assembled in the same manner. Its assembly fixture is positioned atop the lower skin section and joined to it. The staging rocket fairing and support structure is assembled after assembling the lower and center section. The nose fairing is spin formed. After spinning,

TABLE 5.4.1.3-II TOOL LIST - AFT ATTACHMENT STRUCTURE

Skin Trim Fixture
Skin Heat Treat Fixture
Support Post Mill Fixture
Skin Storage Rack
Upper Ring Assembly Fixture
Upper Ring Turning Fixture
Ring Heat Treat Fixture
Staging Rocket Fairing Die
Skin Assembly Fixture
Reinforcing Ring Stretch Form Die

5.4.1.3 (Continued)

the nose assembly is trimmed and positioned on the lower assembly in the assembly fixture.

The reinforcing rings are assembled from rolled aluminum channel quadrants. The rolled quadrants are assembled into a complete ring in a ring assembly fixture. The completed ring is then placed in the nose assembly fixture.

The forty Z-sections are trimmed to length from an extrusion and positioned in the assembly fixture prior to installing the skins. The entire structure is covered with an ablative coating one-eighth-inch thick. The application of ablative material to the exterior of the cone will require development of manufacturing techniques and evaluation of application equipment. The problems encountered depends upon the material selected.

The nose cone will then be shipped with the forward and aft attachment structures to the solid motor contractor's facility for assembly to the solid motor. Table 5.4.1.3-III lists the major tools required for the fabrication of the solid motor nose cone.

5.4.1.4 Manufacturing Schedule

The solid motor stage components manufactured at Michoud will be fabricated in accordance with the schedule shown in Figure 5.4.1.4-1.

5.4.1.5 In-Plant Test and Checkout

In-plant testing and checkout will include all normally specified solid motor in-process tests of raw materials, components, subassemblies and systems. Following is a list of other in-plant tests of completed subsystems and/or major components.

Stage Sequencing System Test — Verification of the operation of stage sequence and control distributor function.

Stage Instrumentation System Channel Identification Test — Verification of the operation of stage telemetry system to assure that each channel has only the assigned function.

Range Safety System Test — Verification of the generation of arming, engine cutoff, and SRM destruct signals by transmitting open- or closed-loop RF commands to the stage range safety command receivers.

TABLE 5.4.1.3-III TOOL LIST - SRM NOSE CONE

Nose Fairing Spinning Die

Ring Quadrant Rails

Ring Assembly Fixture (Five Different Required)

Skin Trim Fixture (Two Different Required)

Staging Rocket Fairing Assembly Fixture

Skin Handling Fixture

Skin Storage Rack

Cone Handling Fixture

Z Section Trim Fixture

Fairing Form Die

Fairing Base Form Block

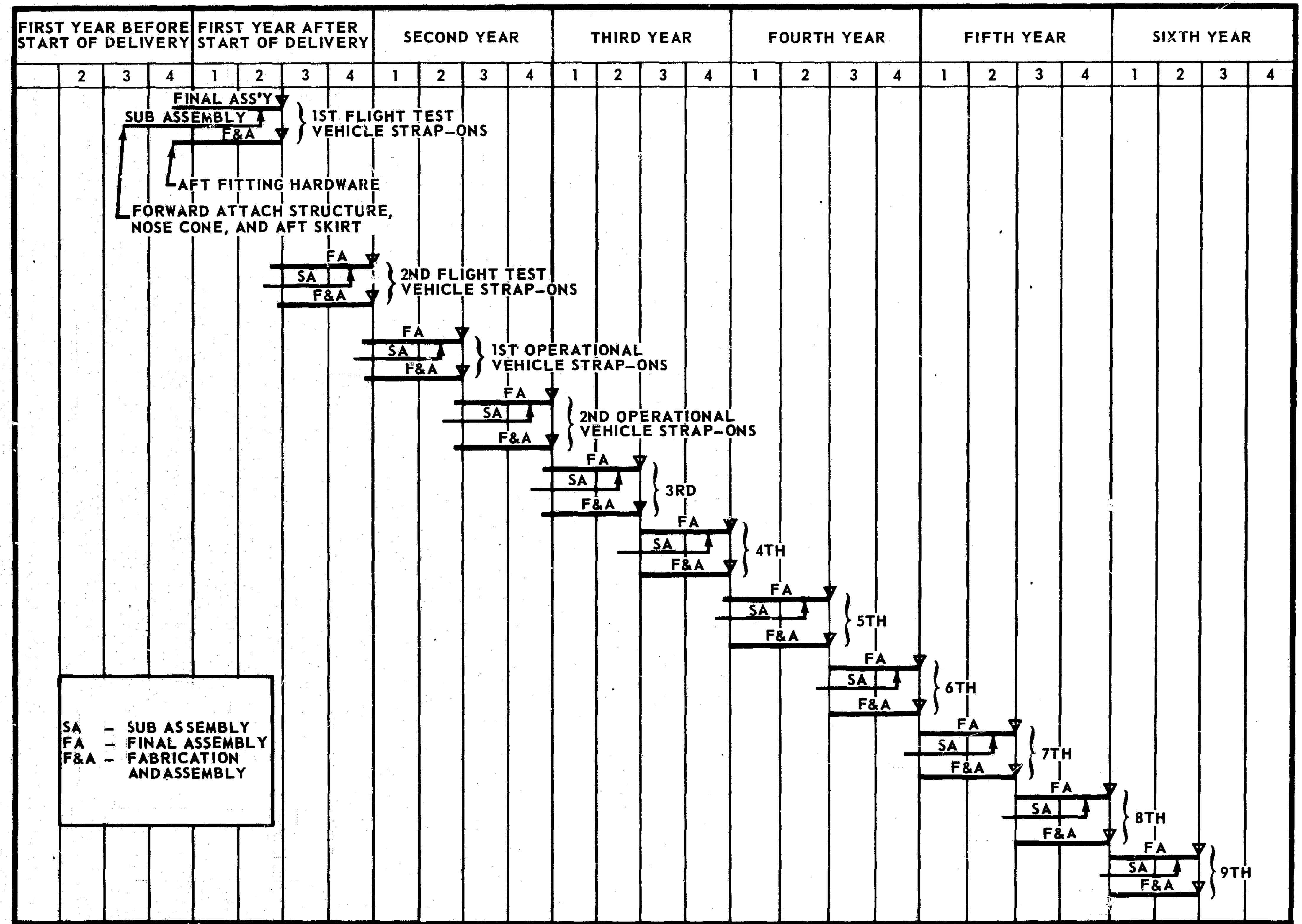

FIGURE 5.4.1.4-1 260-INCH SRM HARDWARE MANUFACTURING SCHEDULE (Michoud)

5.4.1.5 (Continued)

Simulation Flight Test — Verification of the operational readiness and mutual compatibility of stage and SRM systems for launch and flight.

Commanded Premature SRM Separation System Test — Verification of the presence of separation, and destruct signals only when the proper combination of malfunction signals (as generated by the computer) are received from the computer.

Stage Electrical Connections Test — Performance of the quality/acceptance tests to prove proper separation of electrical connectors occurs on SRM staging.

Separation System Test — Verification of the presence of an acceptable SRM separation firing signal when the separation firing system is actuated.

Stage Power Systems Test — Verification of the presence of stage DC power at SRM connection points when the proper signals are generated.

260-Inch Case Pressure Test — Performance of a hydro-test of the solid motor case to prove capability to withstand pressure encountered during launch and flight operations.

Solid Motor Thrust Vector Control (TVC) Systems Test — Performance of a test of the TVC system to determine electrical and hydraulic system functional operation. Calibrate the TVC deflection angle and response rate to the input signals.

These tests will also be repeated at the receiving and inspection dock at MILA to assure functionality (after transportation) prior to assembly of the solid stage to the core vehicle. Figure 5.4.1.5-1 is the R&D test schedule where many of these tests will be developed.

5.4.2 SRM Stage Resource Implications

The resources for the SRM stages will differ between the AMLLV and MLLV. The similarity between the SRM's minimizes the effect of design on the resources. The production rate of 24 per year for the AMLLV and 16 per year for the MLLV will cause the major resources differences.

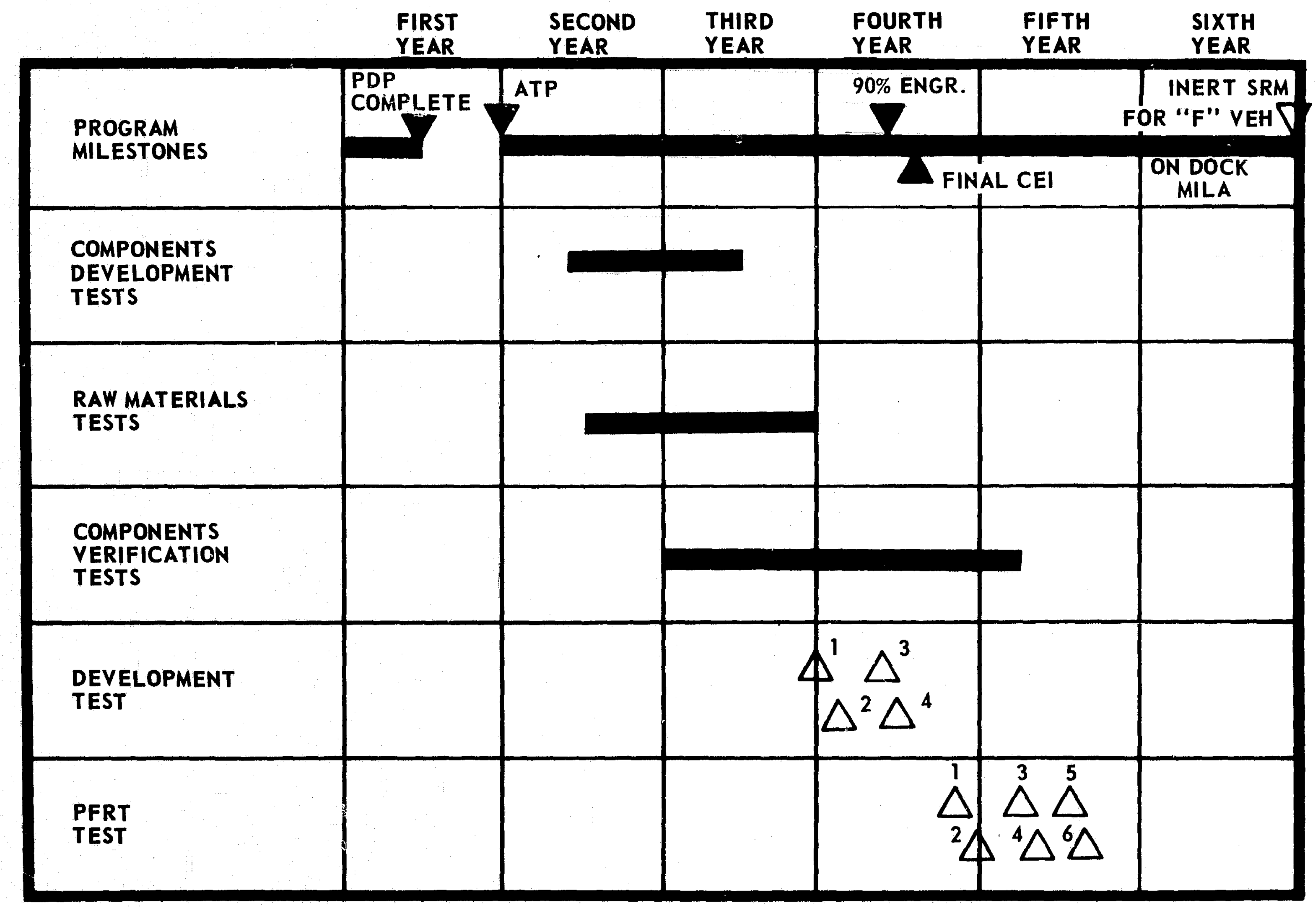

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FIGURE 5.4.1.5-1 TEST SCHEDULE, 260-INCH SOLID MOTOR STAGE

5.4.2.1 Manpower Resource Implications

Tables 5.4.2.1-I and -II have been compiled to depict manpower reouirements for the manufacture of the SRM stages for the AMLLV and MLLV, respectively. Aerojet General submitted numbers for the SRM motor, which will be a contract item. The structures required to convert each motor into a strap-on stage will be manufactured at Michoud and shipped to the SRM motors manufacturer for assembly.

Only very general estimates are available at this time on the SRM motor from the SRM manufacturer. The estimates and calculations on the SRM structures required to convert the SRM motor into a strap-on stage were in much greater detail, and will appear in the section costing the SRM stage. Tables 5.4.2.1-I and -II contain a summary of calculations pertinent to this report.

Recurring manhours to fabricate and assemble the hardware are shown, and also nonrecurring manhours to cover the get ready costs for each major structure. A comparison of these costs to the "get ready" tooling costs is included.

5.4.2.2 SRM Material Resources Implications

Material cost have been estimated and calculated in some detail, and will appear in Document D5-13463-4 and -5 of this study. Tables 5.4.2.2-I and 5.4.2.2-II were prepared to summarize these costs for the SRM portion of the resource implications and appear below.

5.4.2.3 SRM Tooling

The tooling required to produce the production solid motor stages is shown below in Table 5.4.2.3-I for the AMLLV and MLLV SRM stages.

Table 5.4.2.3-II below lists the Category "A" tooling manhours required for the SRM stage structures. As noted, tooling manhours for the SRM motor are included in the tooling costs submitted by Aerojet General, Table 5.4.2.3-I.

5.4.2.4 SRM Facilities

The facilities required for the solid motor stage will be located at the solid motor contractor facility and at the Michoud facility. The subcontractors facilities (for major elements such as the case and nozzles) are included in the components costs but were not investigated as a part of this analysis.

TABLE 5.4.2.1-I AMLLV SRM STAGE COSTS: RECURRING & NON-RECURRING

SRM Structures	Recurring Mfg. (Man Hours) Manufacturing	Non-Recurring "Get Ready" (Man Hours)	Tooling Materials (Dollars) Non-Recurring
Attach Structure	153,854	1,759,000	$1,111,157
Aft Skirt	45,819	332,000	207,561
Nose Cone	69,059	839,000	529,938
Attach Fittings	32,436	113,000	68,476
Sub Totals	301,168	3,043,000	$1,917,132
Aerojet General	78,000	234,000	* $58,801,000
Total	379,168	3,277,000	** $60,718,132

* Combines Material & Manhours
**Less GSE

TABLE 5.4.2.1-II MLLV SRM STAGE COSTS: RECURRING & NON-RECURRING

SRM Structures	Recurring Mfg. (Man Hours) Manufacturing	Non-Recurring "Get Ready" (Man Hours)	Tooling Material (Dollars) Non-Recurring
Attach Structures	126,000	1,674,000	$1,055,600
Aft Skirt	38,000	315,000	197,183
Nose Cone	57,000	797,000	529,938
Attach Fittings	26,000	107,000	65,053
Sub Totals	247,000	2,893,000	$1,847,774
Aerojet General	63,000	212,000	* $41,941,000
Total	310,000	3,105,000	** $43,788,774

* Combines Manhours & Materials
**Less GSE

TABLE 5.4.2.2-I AMLLV SRM STAGE MATERIAL COST

SRM Structures	Material $ (Recurring)	Material $ (Non-Recurring)
Attach Structure	$ 192,225	$1,784,000
Aft Skirt	53,030	334,000
Nose Cone	50,650	850,000
Attach Fittings	33,135	111,000
Sub-Total	$ 329,040	$3,079,000
Aerojet General	6,792,000	*
Totals	$7,121,040	$3,079,000
*Included in Tooling Material		

TABLE 5.4.2.2-II MLLV SRM STAGE MATERIAL COSTS

SRM Structures	Material $ (Recurring)	Material $ (Non-Recurring)
Attach Structure	$ 121,294	$1,694,000
Aft Skirt	33,462	318,000
Nose Cone	50,650	802,000
Attach Fittings	20,908	106,000
Sub-Total	$ 226,314	$2,920,000
Aerojet General	5,311,000	*
Totals	$5,537,314	$2,920,000

*Included in Tooling Material

TABLE 5.4.2.3-I AMLLV & MLLV SRM STAGE TOOLING COSTS

CATEGORY "A" - GET READY COSTS

	AMLLV Total Cost	MLLV Total Cost
1. Tooling Design Labor	$ 802,000	$ 650,000
2. Tooling:		
Development		
Process Tooling	4,630,000	4,201,000
Tooling Maintenance & Modification	2,063,000	1,558,000
Chamber Tooling	4,504,000	3,534,000
Nozzle Shell Tooling	656,000	656,000
Ablatives & Exit Cone Tooling	960,000	822,000
Auxiliary Power Unit Tooling	219,000	219,000
Ignition Tooling	104,000	104,000
Inspection Tooling	975,000	975,000
Production		
Process Tooling	20,456,000	12,820,000
Chamber Tooling	14,980,000	9,440,000
Nozzle Shell Tooling	2,322,000	1,460,000
Ablatives & Exit Cone Tooling	1,983,000	1,390,000
Inspection Tooling	300,000	300,000
Subtotal	$54,954,000	$38,129,000
G/A @ 7%	3,847,000	3,812,000
Total Cost - AEROJET GENERAL GENERAL TOOLING (Including Material & Manhours)	$58,801,000	$41,941,000
3. Ground Support Equipment (GSE)	$ 762,000	$ 762,000
4. Structures (Michoud)		
Nose Cone	529,938	529,938
Forward Attachment Structure	1,111,157	1,055,600
Aft Skirt	207,561	197,183
Fittings	68,476	65,053
Subtotal - Structures	$ 1,917,132	$ 1,847,774
GRAND TOTAL - CATEGORY "A" TOOLING	$61,480,132	$44,550,774

TABLE 3.4.2.3-II AMLLV AND MLLV SRM STAGE TOOLING MANHOURS, NON-RECURRING (MICHOUD STRUCTURES)

ITEM			AMLLV	MLLV
STRUCTURES			1,095,504	1,055,871
	AMLLV	MLLV		
Nose Cone	302,822	302,822		
Fwd. Attach. Struct.	634,947	603,200		
Aft Skirt	118,606	112,676		
Fittings	39,129	37,173		
PROPULSION/MECHANICAL			*	*
ELECTRICAL/ELECTRONICS			*	*
INSTRUMENTATION			*	*
FLIGHT CONTROL			*	*
SRM			*	*
STAGE ASSEMBLY			*	*
TOTAL - STRUCTURES M/HRS. (MICHOUD)			1,095,504	1,055,871
*Tool Manhours Included in Aerojet Tooling Material.				

5.4.2.4 (Continued)

Solid Motor Contractor's Facility Plan — The major facilities required for the solid motor development and production are the Cast, Cure, and Test (CCT) facility, with access by waterway. A production of 24 SRM's per year for the AMLLV or 16 SRM's per year for the MLLV will require additional CCT facilities. For the MLLV requirements, the existing CCT facility plus three additional CCT facilities would be required. For the AMLLV requirements, the existing CCT plus four additional CCT facilities would be required. In addition, the existing CCT facility must be provided with water access. The existing manufacturing and support facilities must be increased to meet this higher production rate. (Current capability is approximately four per year.)

Solid Motor Michoud Facility Plan — The items requiring new facilities are the forward and the aft attachment structures and the nose cone. Attachment struts, fittings and brackets will be fabricated using equipment proposed for the core stage.

Assembly Area — An assembly area of approximately 45,700 square feet will be required to accommodate eleven assembly operations for the forward skirt attach structure, the nose cone and the aft flare. Three sets of tooling fixtures will be required for each of these operations. New facilities provided in this area will be footing foundations and utilities to work positions, in addition to two new 15-ton overhead cranes.

Office and Miscellaneous — A foreman's office and personnel desk and eating area of approximately 2,300 square feet will be required to support assembly activities, with the facilities costs incurred for the office structure, air-conditioning and utilities.

Dolly and Major Component Storage Area — An area occupying 4,800 square feet for dolly staging, storage and major component storage will be required, with facilities costs incurred through floor sealing and striping.

Paint Booth — A 1,600 square foot, 35-foot high booth with water wash, fire protection, industrial ventilation and paint spray equipment as well as paint storage facilities will be required to paint the detail parts and the major components.

Packaging Area — A fenced-in 4,200 square foot packaging area equipped with a jig crane, cut-off saw, radial saw and heat seal equipment will be required to package components and assemblies.

Stores — A 9,300 square foot area between Major Paint and Ship, and Component Test will be utilized for storage of sheet stock, parts, and subcomponents. The area will be equipped with office space and shelving.

5.4.2.4 (Continued)

Facility and capital equipment costs are shown in Table 5.4.2.4-I for Category "A" nonrecurring costs. Table 5.4.2.4-II reflects the Category "C" recurring maintenance costs for capital equipment.

5.4.2.5 SRM Facilities Implementation

The schedule for implementation of the changes to Michoud are shown in Figure 5.4.2.5-1. The schedule for solid motor facility implementation is shown in Figure 5.4.2.5-2.

Schedule Plan — The schedule plan for the solid motor stage is shown in Figure 5.4.2.5-3. The solid motor stage activity starts with the program definition phase (PDP). During this period, the planning for the solid motor stage program is accomplished. This includes 1) the design planning for the solid motor and its stage components, 2) the definition of the processes to be used to produce and test the motor, its components, subassemblies, and assemblies, 3) the definition of the facilities, tooling, GSE, and checkout equipment required, 4) the long range planning necessary to meet the development, PFRT, and delivery schedules, and 5) definition of the test requirements to provide a reliable solid-motor stage. With the authorization to proceed with hardware, acquisition of long-lead time material, tooling, and facilities will be initiated. The Cast, Cure and Test facilities requirements are the long-lead time facilities for the production solid motors. Existing facilities will be used for the developmental motors. The PFRT motors will be manufactured in the new facilities. Approximately 12 months will be required to activate a new Cast, Cure and Test Facility.

The work on the other facilities can be conducted concurrently, and will be ready at three month intervals from the first operational facility. The manufacturing and other support facilities do not require as long-lead time. New facilities for the production motors will be available during the production of the PFRT units and may be phased into the program at this point.

The Michoud facilities for the solid motor stage components will be ready 24 months from the completion of the manufacturing plan. This allows ample time to phase this component into the solid motor stage schedule without difficulty.

The schedule for the development motor tests and the PFRT testing allows sufficient time to analyze test results and make changes where necessary. These times are comparable to other large motor test schedules and can be readily met.

Delivery of the operational motors can be achieved if the Cast, Cure and Test facilities are completed on schedule. No difficulty can be seen in meeting the schedule shown in Figure 5.4.2.5-3.

TABLE 5.4.2.4-I AMLLV AND MLLV SRM MANUFACTURING FACILITY AND EQUIPMENT COSTS - NON-RECURRING

ITEM	AMLLV	MLLV
BRICK & MORTAR		
MICHOUD FACTORY MODS.	$ 3,320,000	$ 3,230,000
EQUIPMENT		
HANDLING EQUIPMENT	457,000	434,000
CAPITAL EQUIPMENT	1,937,000	1,840,000
SRM		
PRODUCTION FACILITY * (HOMESTEAD, FLORIDA)	$67,667,000	$45,100,000
TOTAL FACILITIES & EQUIPMENT	$73,381,000	$50,604,000
*Includes Equipment		

'ABLE 5.4.2.4-II AMLLV AND MLLV SRM MANUFACTURING FACILITY AND CAPITAL EQUIPMENT MAINTENANCE - RECURRING COSTS

ITEM	AMLLV	MLLV
BRICK & MORTAR	*	*
MICHOUD	$ 74,000	$ 74,000
HOMESTEAD	**	**
CAPITAL EQUIPMENT		
MICHOUD	$134,000	$128,000
HOMESTEAD	**	**
TOTAL	$208,000	$202,000

* These Costs are Recurring Per Year
** Included in Aerojet SRM Recurring Cost

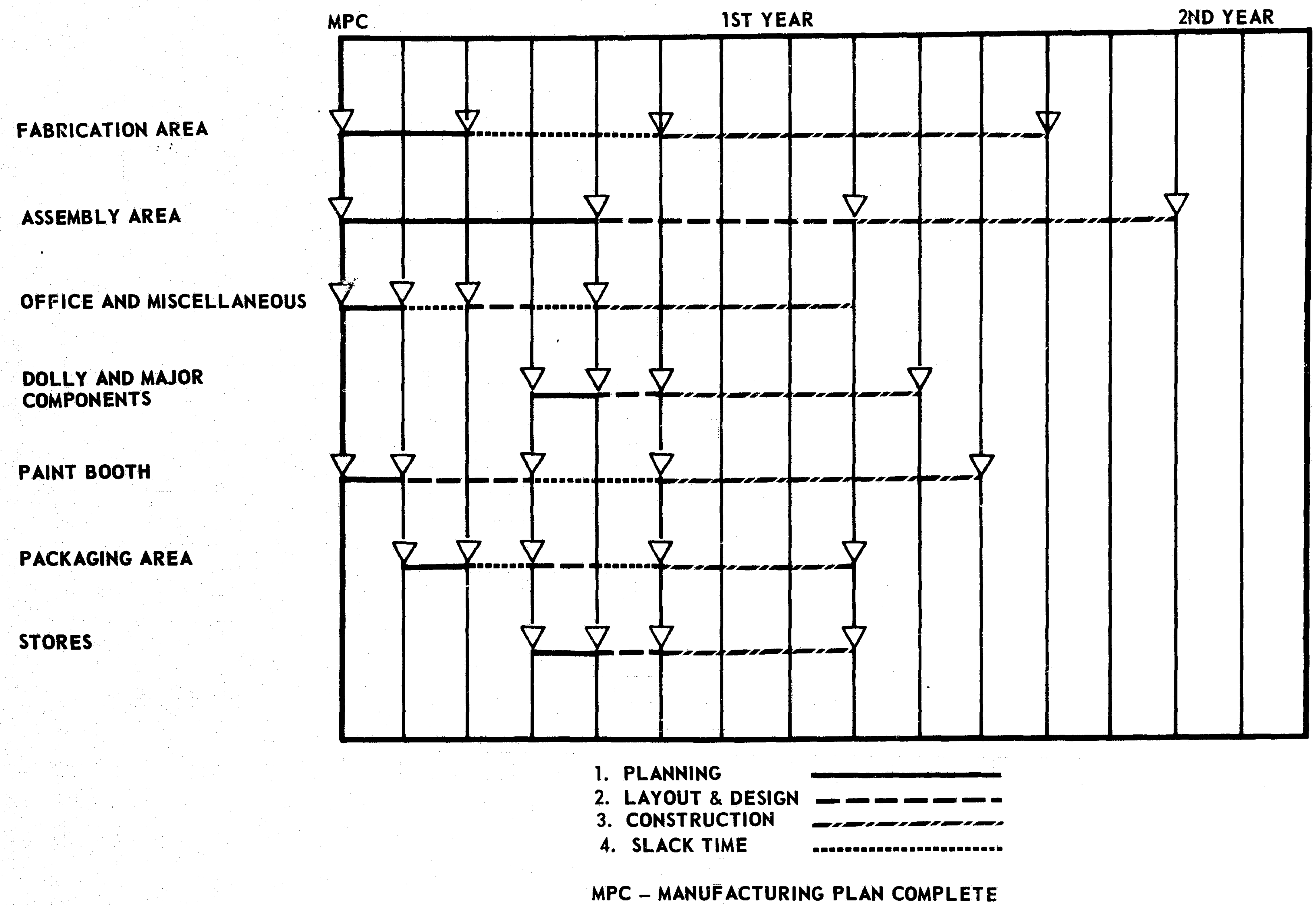

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FIGURE 5.4.2.5-I MICHOUD SOLID MOTOR COMPONENTS IMPLEMENTATION SCHEDULE

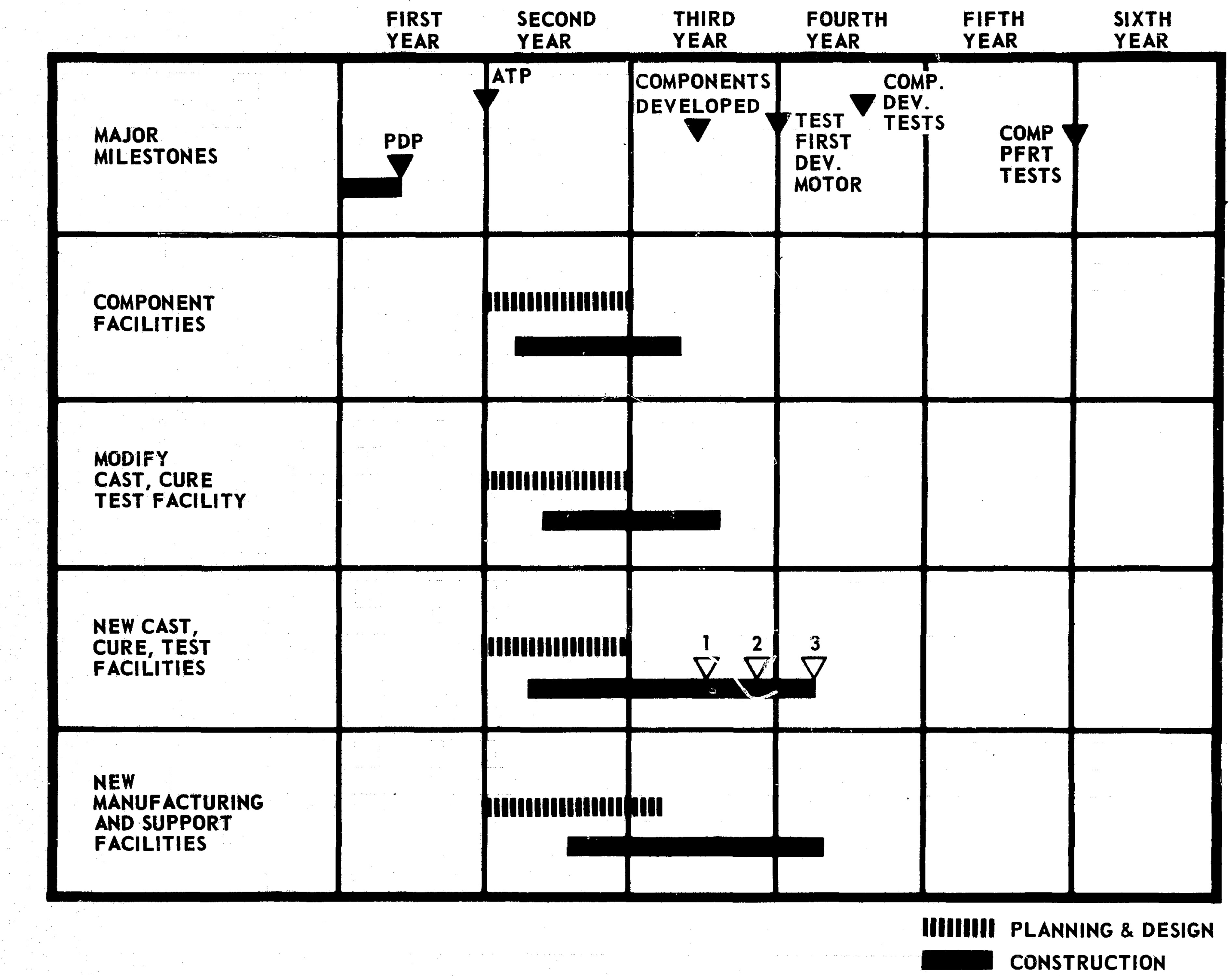

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FIGURE 5.4.2.5-2 SOLID MOTOR FACILITIES IMPLEMENTATION SCHEDULE

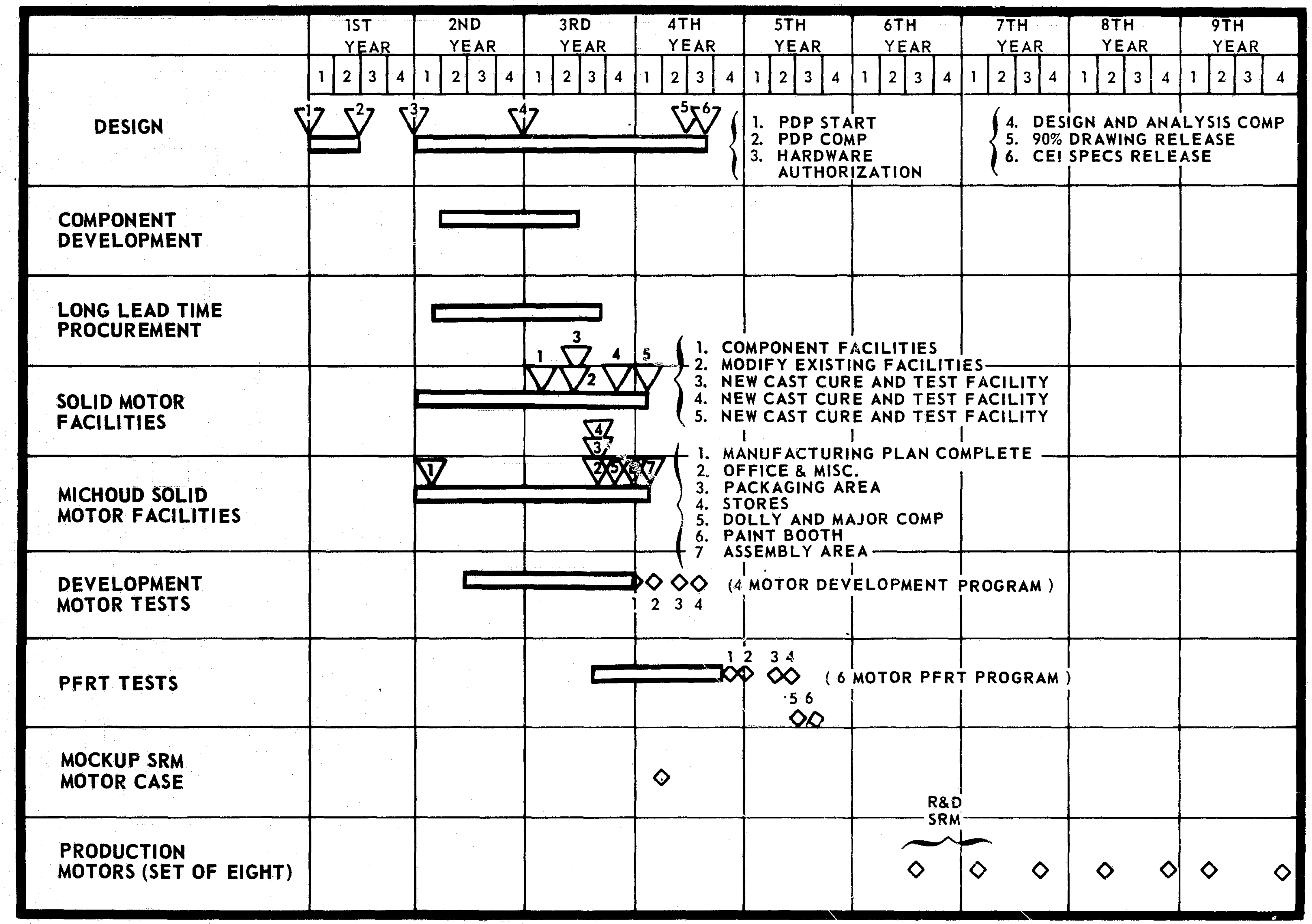

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FIGURE 5.4.2.5-3 MOTOR PHASING, SOLID MOTOR STAGE

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6.0 TRANSPORTATION PLAN

This plan discusses the handling and transportation considerations and defines the selected modes and their resource requirements.

Transportation of the MLLV and AMLLV main stages and injection stages present problems similar to those encountered in the Saturn program. Inputs were therefore obtained from The Boeing Company organizations which were active on the Saturn V program at Michoud, Huntsville, and KSC. This information served as a baseline for the determination of handling and transportation methods, selection of equipment, and other resources analyses.

Inputs for SRM stage handling and transportation were provided by Aerojet General and/or extrapolated from applicable prior NASA study contracts.

This section defines transportation and handling modes of the vehicle stages and component structures at the manufacturing plants, transport to the launch facilities, and handling and transport at the launch facility for loading, static firing, refurbishment, stacking of the vehicle stages and launch. All transportation and handling modes and hardware envisioned are within the state-of-the-art. Because of the great sizes and weights involved, all new equipment will be needed.

Transportation and handling for the core and injection stages are planned and discussed jointly, since problems and procedures are similar. A separate section is prepared for the SRM stage transportation plan, because of the greater weights involved and the more complex requirements for maintaining structural integrity and minimizing the hazardous nature of the operation.

Transportation and handling modes and resource requirements were developed according to the ground rule that transportation of the payload and all of the vehicle stages between sites will be by water. Overland transportation will be considered only for the manufacturing sites. Because of the magnitude of size and weight, overland transportation of main core, injection stages and SRM between the manufacturing facility and the launch facility is impractical.

The requirements for transporting and handling the elements of the half size (MLLV) vehicle are basically the same as those of the full size (AMLLV).

The vehicle elements will be transported from the manufacturing facility to the launch facility on towed barges. The capability will exist at the launch facility for direct off-loading from the barge to the launch pad.

Land transportation will be required for the core and injection stages at the manufacturing facility (but not at the launch site). A pneumatic tire transporter was selected for in-plant transportation of the main stage. A 400-ton crane will be required at the manufacturing site. The loaded SRM, however, will be lifted

6.0 (Continued)

directly from the casting pit at the SRM contractor's facility and placed on board a barge. At the launch site, the SRM's will be lifted directly from the barge and placed in position on the launch pad by a mobile overhead gantry crane.

This same track mounted gantry will also be used to lift the main and injection stages.

The injection stage will be transported in-plant in an upright position on a pneumatic tire transporter. Handling of the injection stage will be accomplished with cranes designed for the main stage.

The barges used to transport the SRM stages from the manufacturing site to the launch pad will also serve as storage facilities. These barges will be anchored in protected, yet remote locations, and towed to the launch pad as required for vehicle assembly.

6.1 MAIN STAGE HANDLING AND TRANSPORTATION PLAN (PNEUMATIC TIRE UNIT)

An overland transporter similar in configuration to the present S-IC stage transporter, but capable of handling the 375,000-pound, 57-foot diameter MLLV main stage (or the 750,000-pound, 72-foot diameter AMLLV main stage), was the selected concept. The present S-IC stage transporter is capable of handling 600,000 pounds, including its own weight. The load-carrying ability is distributed 400,000 pounds on the front (or thrust structure) dolly and 200,000 on the rear (forward handling ring) dolly. To handle the larger diameter of the MLLV (and larger weight and diameter of the AMLLV), new transporters are required. All of the wheels, tires, steering cab and mechanisms of the S-IC transporter are, however, applicable to the new transporters.

This concept is compatible with existing methods and requires no new technology. This concept provides a maximum degree of mobility at the manufacturing facility. Hard-surfaced roadway will be required to support the pneumatic tire wheels.

Handling equipment for the main stage and component structures at the manufacturing site is further detailed and illustrated in Section 5.2, "Main Stage Manufacturing Plan", paragraph 5.3, "Injection Stage Manufacturing Plan", and in paragraph 5.4, "SRM Stage Manufacturing Plan".

Launch facilities handling equipment is further detailed and illustrated in Section 7.0.

6.1 (Continued)

Towed barges were selected to accomplish the water transportation of the main stage and injection stages. Initial sizing of the barge indicated required dimensions of approximately 250 feet long, 100 feet beam and an extreme width for clearance of roughly 125 feet. Towed barges are compatible with existing mode of hauling elements of its magnitude. There is no requirement for development of any technology associated with this mode. This concept will require the construction of new barges.

6.2 SRM STAGE HANDLING AND TRANSPORTATION PLAN

Processing of 260-inch diameter motors at the Aerojet-Dade Division (A-DD) facility will utilize a concrete caisson termed the Case, Cure and Test (CCT) facility. The empty motor chamber will be positioned vertically in the CCT with the aft flange approximately at ground level for subsequent propellant loading and curing. After propellant cure and removal of the casting core, motor final assembly will be conducted while the motor is still in the casting position in the CCT. The nozzle, TVC system, aft attachment structure and other stage components (exclusive of the forward attachment structure and the nose cone) will then be assembled to the motor. (This method of assembly, with the motor in the vertical position, presents significantly less risk of component damage than for assembly with the motor in the horizontal position.) The motor will be lifted from the CCT and placed on a barge for shipment to the launch facility. While the motor is on the barge in the horizontal position, the forward attachment structure and the nose cone will be installed.

6.2.1 Lifting and Handling Requirements

A fixed derrick system capable of lifts in the 2,000-ton range will be located adjacent to the CCT as shown in Figure 6.2.1.0-1. The system as shown (termed the double-boom stiff-leg derrick, as proposed by American Hoist and Derrick Company) will use a combination of proven "off-the-shelf" components. The system will use booms from American Hoist Models 407 and 509 cranes for struts and main boom assemblies, respectively, and four American Hoist Model 650A lifting hoists.

The 260-inch diameter motor for this study program approaches the limit of lifting capability for the derrick discussed above. American Hoist and Derrick Company is currently developing larger booms and struts and a Model 1300 hoist that is capable of line pulls of at least 50 percent greater than the Model 650A hoist. These components can be combined in a similar derrick configuration with increased lift capacity.

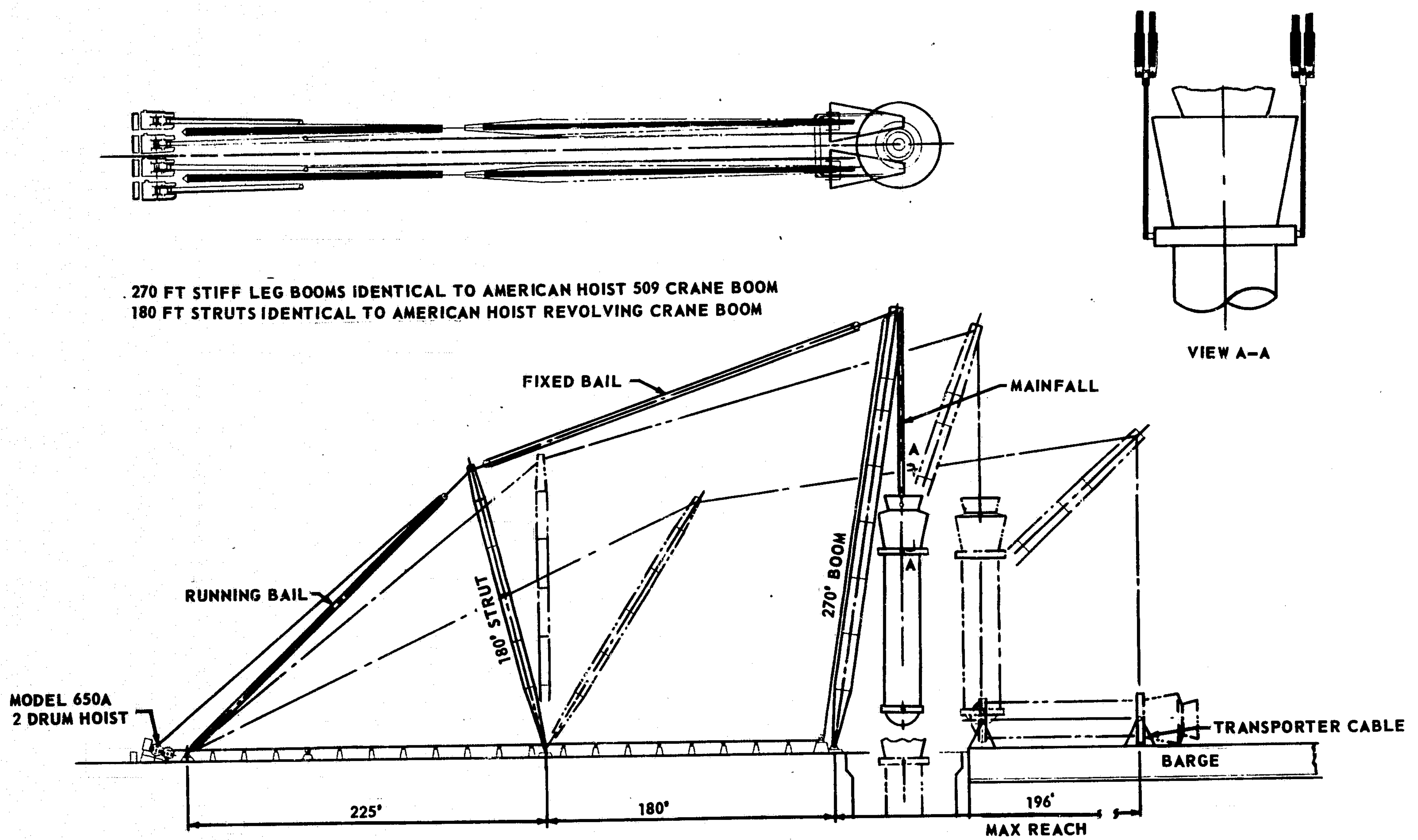

FIGURE 6.2.1.0-1 DOUBLE BOOM STIFFLEG DERRICK SYSTEM

6.2.1 (Continued)

The concept for handling the empty solid motor chamber prior to installation into the cast, cure and test (CCT) facility will require handling rings attached to the forward and aft skirts. These handling rings will be used for all subsequent handling operations up until final assembly of the SRM stage to the launch vehicle.

After the SRM is loaded and cured and the stage components (exclusive of forward attachment skirt and the nose cone) are added to the motor, the fixed derrick will lift the assembly by the aft trunnions on the aft external handling ring (attached at the aft attachment structure stabilizing strut attach station). This handling ring will be fabricated of 2-inch and 4-inch thick T-1 steel plate using box-beam construction, and will be approximately 54 x 32 inches in cross section. Pick-up trunnions will be located at the 0° and 180° positions on each handling ring. The heavy cross section will distribute trunnion loads uniformly about the periphery of the skirt.

Lifting slings will be attached to the two trunnions on the aft handling ring (see View AA, Figure 6.2.1.0-1). The load slings will attach to the double main falls, one set on each of the two booms. The motor will be hoisted from the CCT to a position 25 to 40 feet above ground level to provide clearance for booming out to position the trunnions of the forward handling ring in the barge transporter cradles. The motor will then be rotated to the horizontal position by pivoting about the forward handling ring trunnions with further booming out of the derrick and extension of the main falls as shown in Figure 6.2.1.0-1.

The type of derrick system discussed would not have sufficient reach to position the motor at the center of the barge, and a transporter will be needed for supporting and positioning the motor while on the barge. The transporter used will utilize a metal wheel guide-rail system to enable movement along the barge deck.

After the SRM stage is in final position on the barge, the nose cone and forward attachment skirt will be attached. Final stage checkout will be accomplished on the barge.

The above handling sequence was provided by the Aerojet General Corporation. Other concepts considered have been presented in reports of completed study contracts.* In addition, a study of launch facility considerations for large solid motors has been conducted by McDonnell-Douglas Corporation under Contract NAS10-4802.

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*Martin Company Technical Report, Solid Motor Logistics Study, Vol. III, prepared for NASA, Marshall Space Flight Center, January 1964. Bellcomm, Inc., Report TR-66, 330-2, A Concept for Handling and Launching Large Solid Rockets, Contract NASw-417, MSFC, dated 30 September 1966.

6.2.1 (Continued)

Subsequent AMLLV/MLLV studies identified the requirement for a large overhead gantry at the launch site (see Sections 6.2.3 and 7.0). This gantry could possibly be adapted for use at the manufacturing site.

6.2.2 Transportation: SRM Stages, Manufacturing Site to Launch Facility

Transportation of the SRM stage from the manufacturing site to the launch facility will be by towed barge. The SRM stage will be positioned horizontally on the barge. A canal system will provide access from the A-DD facility to the intercoastal waterway. Use of the intercoastal waterway for the entire distance to KSC would limit barge beam and draft, such that barge lengths in excess of 500 feet would probably be required for adequate flotation. An ocean-going barge, such as shown in Figure 6.2.2.0-1, was selected as preferable. Since the SRM stage will represent a concentrated load to be moved over the barge deck, particular consideration will be given to providing structural adequacy to the barge. The barge will require deck winches, a ballast pumping system, and provisions for SRM monitoring and control.

Structural analysis of the SRM steel chamber indicates that the stability of the chamber will be compromised when supported in the horizontal position at the forward and aft skirts if subjected up or down acceleration loads in excess of approximately $\pm$ .75g. In environments where acceleration loads of this magnitude may be encountered, a pneumatic pressure of approximately 25 psig must be maintained in the motor interior to increase the rigidity, and hence, the stability of the chamber. Structural analyses of the propellant grain under acceleration loads have been performed for a 260-inch diameter motor having a cylindrical length of 1,060 inches. Results of these analyses show good margins of safety for grain structural integrity.

6.2.3 Handling SRM Stage at the Launch Facility

Storage of the 260-inch SRM stages at KSC will be necessitated due to the quantity of SRM stages associated with each vehicle. Storage of the SRM stages will be on the transportation barges which will be moored adjacent to the barge docks. SRM stage checkout and inspection operations will be performed on the barges. The SRM stages will be transported from the docks to the launch pad by barge transportation.

At the launch pad unloading slip the barge will be ballastered down onto caissons. An unloading hoist frame will be lowered and attached to the horizontal trunnion pins (fore and aft) of the SRM stage. (Lifting of the SRM's in this frame and in subsequent operations will be accomplished with "Roll Ramp Actuators". Cost of these units were obtained from the manufacturer, The Philadelphia Gear Corporation, who produced the 1,500,000-pound actuators used by NASA in Huntsville, Alabama,

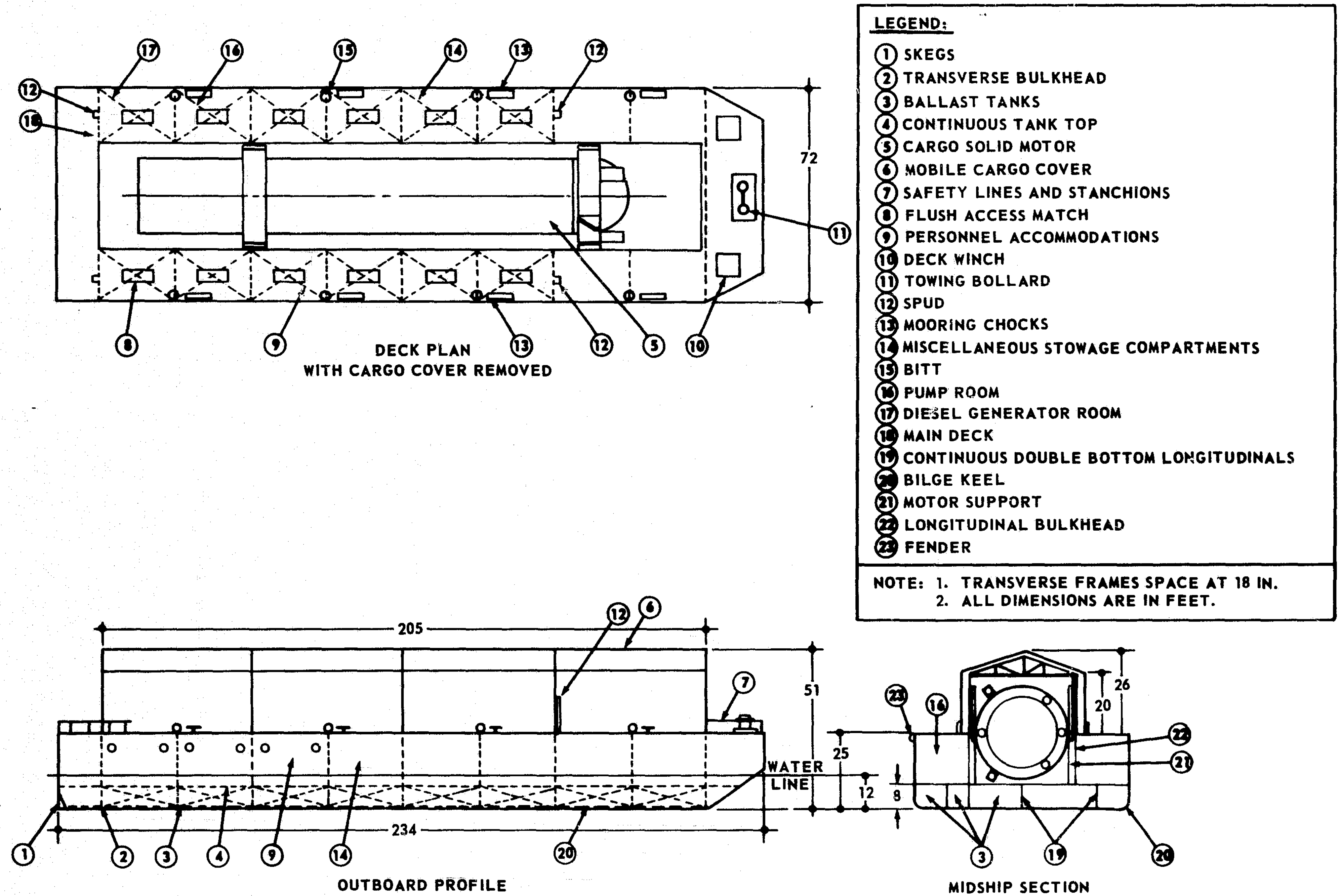


FIGURE 6.2.2.0-1 OCEANGOING BARGE DESIGN FOR THE 260-INCH MOTOR

6.2.3 (Continued)

where four of these actuators were combined to apply a 6,000,000-pound load to rocket casings.) The SRM stage will then be raised to the level of the launch pad deck by eight roll ramp actuators located in the side walls of the unloading slip. The unloading hoist frame with the SRM stage will then be attached to the crosshead of the overhead gantry and transferred horizontally to the SRM stage rotating position. With the SRM stage supported in the rotating fixture at its trunnion points, the unloading hoist frame will be removed. The gantry crosshead will then be attached to the forward SRM stage trunnion. Raising of the crosshead and simultaneous moving of the gantry will rotate the stage into an upright attitude, nozzle end down. The SRM stage will be moved vertically to the launch silo gantry and lowered onto the SRM stage support and alignment fixture. Braces to the forward end of the SRM stage will then be attached, the gantry will be moved away, and the alignment fixture moved back so that the stage is adjacent to the silo wall. The preceding steps will be repeated for each SRM strap-on stage used on the launch vehicle.

The core vehicle will be lowered into position between the SRM stages by use of the gantry crosshead. Each of the SRM stages will be aligned and mated to the core stage. The core in the final launch position will be supported by the SRM's. The support arms from the silo wall to the core will be removed to transfer support to the SRM stages.

Further detail on handling at the launch facility is included in the launch plan (Section 7.0).

6.3 RESOURCE IMPLICATIONS

6.3.1 Main Stage and Injection Stage Equipment

Overall program requirements and ground rules indicate the need for the following major stage transportation articles:

Description	Quantity
Main Stage Barge	1
Injection Stage Barge	1
Main Stage Land Transporter	2
Injection Stage Land Transporter	2
Land Tow Vehicles	2

6.3.1 (Continued)

The following is a description and a cost estimate breakdown of the non-recurring costs related to the AMLLV. MLLV costs are direct estimated percentage reductions. It is assumed, for the purposes of this estimate, that Facilities Equipment Engineering personnel will procure the design, development, and manufacture and delivery from one outside company (see Figure 6.3.1.0-1).

6.3.1.1 Main Stage Barge (AMLLV)

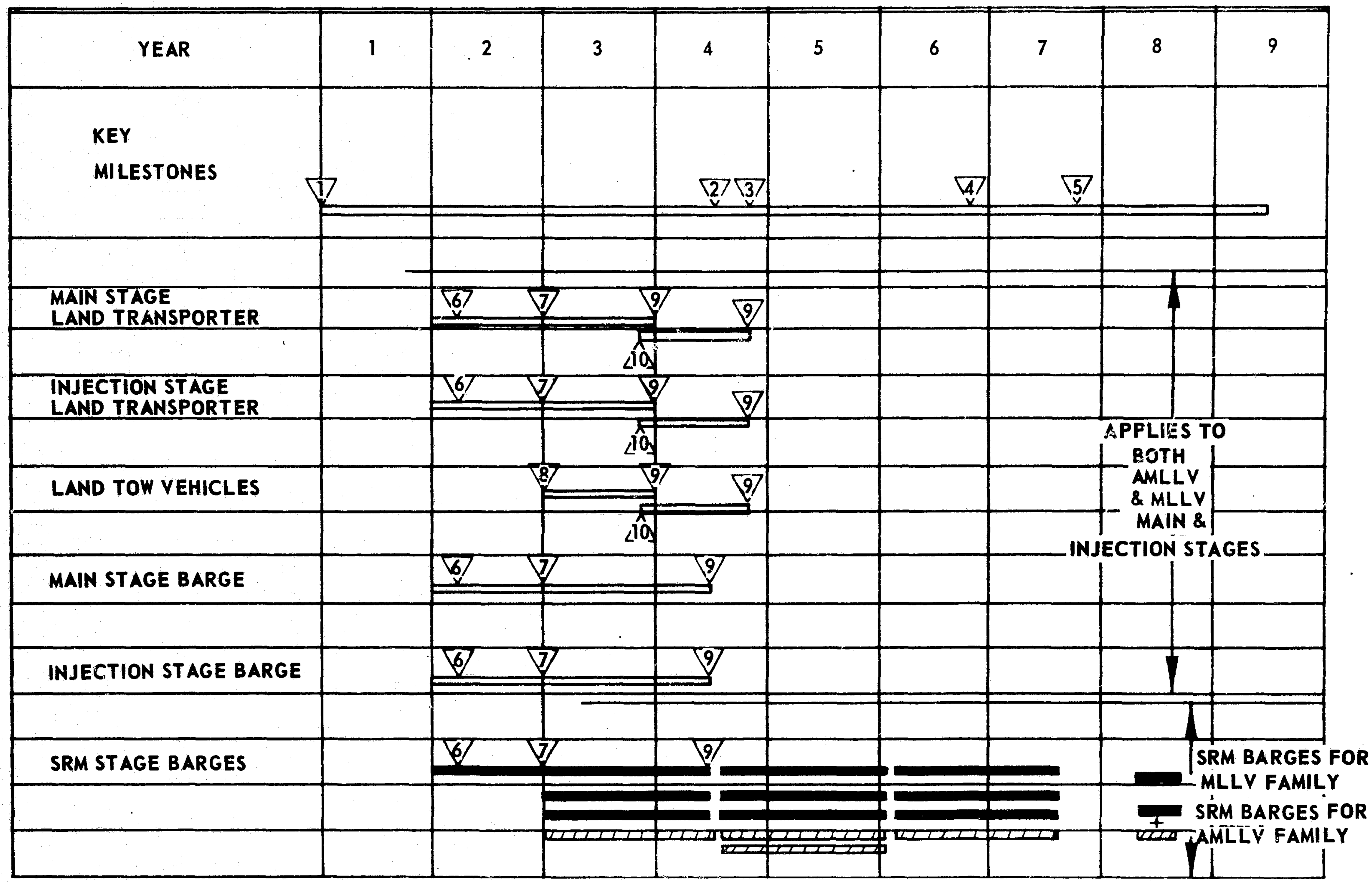
A seagoing barge will be constructed approximately 225 feet long and 120 feet wide. The barge will be equipped with crew quarters, power generation system, and environmental and contamination control. Cargo space will have a retractable cover.

Equipment and Material Cost	$ 504,000	
Fabrication and Inst. Cost	2,750,000	
Design Cost 10%	325,000	
OH and Profit @ 25%	820,000	
	$4,399,000	
5% Criteria and Procurement	220,000	
	$4,619,000	TOTAL

6.3.1.2 Injection Stage Barge (AMLLV)

A seagoing barge will be constructed approximately 100 feet long and 70 feet wide. The barge will be equipped with crew quarters, power generation system, and environmental and contamination control. Cargo space will have a retractable cover.

Equipment and Material Cost	$ 200,000	
Fabrication Cost	1,080,000	
Design Cost 10%	128,000	
OH and Profit 25% Contractor	320,000	
	$1,728,000	
5% Criteria and Procurement	864,000	
	$2,592,000	TOTAL



1 AUTHORIZATION TO PROCEED
2 1ST SET OF LAND TRANSPORTERS REQUIRED
3 2ND SET OF LAND TRANSPORTERS REQUIRED
4 MAIN AND INJECTION STAGE BARGES REQUIRED
5 ALL BARGES REQUIRED

6 DESIGN CRITERIA COMPLETE
7 DESIGN COMPLETE - START CONSTRUCTION
8 LONG LEAD EQUIPMENT ORDERED
9 EQUIPMENT ON DOCK
10 START CONSTRUCTION 2ND UNIT

FIGURE 6.3.1.0-1 STAGE TRANSPORTATION AVAILABILITY TIME LINES

6.3.1.3 Main Stage and Injection Stage Land Transporters (AMLLV)

Land transporters will be constructed similar to the S-IC land transporter (same operating characteristics) capable of transporting the main and injection stages.

Main Stage Transporter AMLLV)

Design and Development Cost	$ 354,000	
Material and Fabrication	770,000	
OH and Profit and Contractor 25%	193,000	
First Unit Cost	$1,317,000	
Second Unit	963,000	
TOTAL 2 UNITS	$2,280,000	
5% Criteria and Procurement	114,000	
	$2,394,000	TOTAL

Injection Stage Transporter (AMLLV)

Design and Development Cost	$ 300,000	
Material and Fabrication Cost	467,000	
OH and Profit for Contractor 25%	117,000	
First Unit Cost	$ 884,000	
Second Unit	584,000	
TOTAL 2 UNITS	$1,468,000	
5% Criteria and Procurement	73,000	
	$1,541,000	TOTAL

6.3.1.4 Tow Vehicle (AMLLV)

Two land vehicles will be standard manufactured items similar to an A-2 Euclid.

Estimate Cost	$ 78,000	1 Unit
Second Unit	78,000	
	$ 156,000	
5% Procurement	8,000	
	$ 164,000	TOTAL

6.3.1.5 MLLV Resources Implications

Considering the MLLV size and weight, less structural material and fabrication time will be required for the barges and land transporters; however, the mechanical and electrical systems will be essentially the same. Also, the design and development cost will not change significantly. From this, it has been determined that a 10 percent reduction in cost is a reasonable assumption, and is reflected as such on the Stage Transportation Summary Sheet (Table 6.3.1.5-I).

6.3.1.6 Maintenance Costs - AMLLV and MLLV

a. Barge Maintenance Cost (AMLLV)

This cost includes barge maintenance and towing service. Towing and maintenance is considered as an outside service contract.

1. Main Stage Barge (AMLLV)

Towing service cost is based on S-IC actuals, from Michoud to Cape Kennedy, which is $2,000/day and a 4-day trip. Because of the increased size, weight, and tug horsepower requirements, the transportation cost is increased to $3,500/day and a 5-day trip or $17,500/trip.

4 Trips/Year @ $17,500	$ 70,000	
Barge Maintenance	90,000	
	$ 160,000/Yr.	TOTAL

TABLE 6.3.1.5-I STAGE TRANSPORTATION SUMMARY COSTS

STAGE TRANSPORTATION	AMLLV		MLLV	
	EQUIPMENT COST NON-RECURRING	EQUIPMENT MAINT. RECURRING/YR.	EQUIPMENT COST NON-RECURRING	EQUIPMENT MAINT. RECURRING/YR.
MAIN STAGE BARGE	$ 4,619,000	$160,000	$ 4,157,000	$160,000
INJECTION STAGE BARGE	2,592,000	72,000	2,333,000	72,000
MAIN STAGE LAND TRANS.	2,394,000	6,000	2,155,000	6,000
INJECTION STAGE LAND TRANS.	1,541,000	4,000	1,387,000	4,000
TOW VEHICLE LAND (2 EACH)	164,000	4,000	164,000	4,000
TOTALS	$11,310,000	$246,000	$10,196,000	$246,000

6.3.1.6 (Continued)

2. Injection Stage Barge (AMLLV)

Towing service is estimated to be approximately the same as S-IC service.

4 Trips/Yr. @ $8,000	$ 32,000
Barge Maintenance	40,000
	$ 72,000/Yr. TOTAL

b. Land Transporter Maintenance (AMLLV)

Land transporter operation is accomplished as a normal transportation function, the cost of which is covered under the manufacturing maintenance cost. Normal routine maintenance to the equipment is estimated as follows:

2 Core Stage Transporters	$ 6,000
2 Injection Stage Transporters	4,000
2 Tow Vehicles	4,000
	$ 14,000/Yr. TOTAL

c. MLLV Maintenance Implications

While the size of the transportation units will be reduced, the systems will remain basically the same. It was, therefore, estimated that the maintenance costs will be the same for either the AMLLV or the MLLV.

6.3.2 SRM Transportation Equipment Requirements

The AMLLV/MLLV program was based on a launch rate of two vehicles per year. Two sets of eight MLLV, or twelve AMLLV solid motors stages per vehicle are required for the maximum configuration, i.e., one set every six months. The time requirements for transportation are defined as follows:

a. Two to three weeks at the solid motor facility to place the solid motor stage on the barge, complete the stage assembly and checkout, and to install environmental instrumentation.

b. One week to transport from the contractor's facility to the launch facility.

6.3.2 (Continued)

c. Three or four weeks to remove instrumentation and conduct inspection and checkout of the solid motor while on the barge. Storage of the solid motor stages will be on the barge until their removal to the launch pad.

d. One week to transport barge back to solid motor processing site with the handling fixtures and instrumentation.

This would allow rotation of the transportation equipment approximately every nine weeks. However, since the SRM stages will be stored on the barges until needed for vehicle assembly, sufficient barges will be required for a complete set of vehicle hardware. Thus, eight MLLV and twelve AMLLV complete sets of transportation hardware, each, delivering one SRM stage each six months, will be provided to meet the program requirements. An additional set will be provided for standby.

6.3.2.1 SRM Transportation Equipment Requirements

The transportation requirements are as follow, with costs of this equipment included in the cost table for ground support equipment (GSE) under barge costs.

Quantity		
MLLV	AMLLV	
9	13	Barges
9	13	Initiator Containers
9	13	Temperature Control Units
9	13	Aft-support Rings
9	13	Forward-support Ring
9	13	Nozzle Closure
18*	26*	Temperature Recorder
18*	26*	Shock Recorder
18*	26*	Temperature Humidity Recorder
9	13	Strong Back Harness

*Assumes one spare per barge

6.3.2.2 SRM Ground Support Equipment (GSE)

Table 6.3.2.2-I, following, prices major items of AMLLV SRM stage GSE. The MLLV SRM stages will require the same equipment as that required for the AMLLV SRM stages; therefore, the costs shown in this table are applicable to both programs, except for the reduction in cost of the barges.

The cost of nine barges for the MLLV program is $18,000,000; therefore, the total cost for the MLLV GSE is $18,762,000.

TABLE 6.3.2.2-I SRM GROUND SUPPORT EQUIPMENT COSTS, AMLLV & MLLV

		AMLLV	MLLV
1.	Electronic Checkout Van	$ 437,000	$ 437,000
2.	Hydraulic Power Servicing Unit	51,000	51,000
3.	Motor Package Pressurization Unit	32,000	32,000
4.	Leak Detection Unit, Helium Type	19,000	19,000
5.	Pneumatic Power Supply Cart	36,000	36,000
6.	Nozzle/TVC Alignment Kit	20,000	20,000
7.	Maintenance Stands	123,000	123,000
8.	Environmental Monitoring Equipment	14,000	14,000
9.	Handling Equipment	30,000	30,000
10.	Barges (13) *	26,000,000	18,000,000
	TOTAL GSE	$26,762,000	$18,762,000

* (1 spare)

7.0 LAUNCH OPERATIONAL SEQUENCE AND FACILITY PLAN

Launch of the Advanced Multipurpose Large Launch Vehicle (AMLLV) and the half size (MLLV) vehicle will require complete new facilities and operational procedures. A fixed, rather than mobile system as used for the Saturn V, is the basic system proposed. The launch complex will serve as: 1) the static firing stand for the core and injection stages, 2) the vertical assembly and checkout facility for the entire vehicle, and 3) the launch facility.

The load lifting and transport concept is similar to the traveling gantry cranes that are used in shipyards. In this case, the gantry is a large inverted "U" frame. The traveling feature is accomplished by wheeled trucks on rails under each leg. Flight hardware is lifted from the barge in a two step operation, then transported to the launch pad silo or refurbishment area for test and checkout. Complete capability will exist at the launch facility for test and checkout, static firing, refurbishment, vehicle stacking and launch. This section includes launch concepts applicable to either the AMLLV or the half size MLLV. Detailed sequential operations are presented, from which man loading and estimated man-hour expenditures for each launch were determined. A listing of capital equipment and facilities description is included, all of which are costed in Volumes III, IV and V of this final report.

Inputs for this plan were received from the NASA and The Boeing Company facilities located at Michoud, Huntsville and KSC.

Various considerations were proposed and evaluated, such as the location of the launch site, launch complex responsibilities and capabilities, transportation and handling techniques, etc. The decision to locate the launch complex on land for the purpose of this study was made as a matter of convenience, recognizing that all but the smaller launch vehicle configurations must be further removed from centers of population. This automatically dictates an off-shore location at a selected point on the continental shelf.

7.1 GENERAL BACKGROUND DATA

The launch facility for either the AMLLV or MLLV will consist of a:

Launch pad,
Test and Launch Control Facility,
Launch Equipment Shop,
SRM Receiving, Test and Storage Area,
Fuel Barge Docking Facility,
Other Facilities as required: e.g., camera and observation sites, cross country piping between fuel barge docking facility and launch pad, etc.

7.1.1 Launch Site Ground Rules

1. Launch rate is evenly timed, i.e., every six months;
2. Launch site will be in the vicinity of Cape Kennedy;
3. Mating of SRM and injection stage to the core stage will be at the launch site;
4. Siting of launch pads will be based upon 20 percent TNT equivalent yield of solids when mounted on fueled core, with 60 percent TNT equivalent yield of LH_2/LOX;
5. The vehicle, supported in the launch stand at its holddown points, must be capable of withstanding a hurricane, but not necessarily without braces or tie downs (i.e., not self supporting under hurricane conditions).

7.1.2 Launch Site Considerations - AMLLV and MLLV

Launch of the half size (MLLV) vehicle will be from a facility similar to that required for the full size (AMLLV) vehicle. Due to the requirements to launch the core stage by itself or the core stage plus the SRM strap-ons, two sets of mounting or holddown fittings are required for either the AMLLV or MLLV.

The SRM strap-on used on the smaller (MLLV) vehicle weighs about 1610 tons, versus the 2000 ton weight of those used on the full size (AMLLV) vehicle. Even with the approximate reduction in weight of 400 tons, the requirements for lifting and positioning these motors remain basically unchanged.

Final vehicle assembly and checkout will be at the launch position.

The location of the launch site is required to be 60,000 ft., away from unprotected personnel as established by the 120 db sound pressure line for the MLLV and 140,000 for the AMLLV. The 0.4 psi blast overpressure stand-off distance is about 3.4 miles for the MLLV and 4.25 miles for the AMLLV.

7.1.3 Acoustic Environment

The predicted far field OASPL acoustic environments for the MLLV with eight 260 inch SRM strap-ons and for the single-stage-to-orbit vehicle are presented in this section.

The environments were extrapolated from the AMLLV predicted environments. Therefore, the basic assumptions and method of analysis for the AMLLV also apply to the MLLV acoustic prediction.

The following conditions were assumed:

1. The vehicle is stationary on the pad;
2. A single deflection flame bucket and a lumped exhaust stream are assumed;
3. The sound pressure levels from multi-engine sources are corrected by the square root of the number of engines;

7.1.3 (Continued)

4. Acoustic environment in the horizontal is symmetrical about the centerline of the exhaust from the flame bucket;
5. Atmospheric conditions are standard with no adverse temperature or wind gradients.

The power of a rocket noise source is determined from engine parameters such as thrust, exhaust gas exit velocity, nozzle exit diameter, flow rate, and number of engines. The acoustic environment is predicted by applying these power values to an empirical normalized spectrum function developed from rocket engine static test firings. The acoustic power spectrum function is proportional to the power per unit band width radiated by the source. Empirical corrections are made for near field effects and directional properties of the acoustic source when the exhaust stream is deflected.

The predictions, at the base of the vehicle, are considered conservative because corrections for finite amplitude were not made. Finite amplitude corrections would account for thermal losses in wave propagation of high intensity noise and would reduce the predicted acoustic environment.

Far field acoustic environment resulting from zero staging of the vehicle consisting of the MLLV core with eight 260 inch solid rocket motor stages is shown in the topography plot in Figure 7.1.3.0-1. Overall sound pressure levels (OASP) at 120 db, 130 db, and 140 db are shown. The single-stage-to-orbit vehicle far field acoustic environment at launch is shown in Figure 7.1.3.0-2. The OASP levels of 120 db, 130 db, and 140 db are shown.

An acoustic power source is determined from rocket engine parameters by means of the normalized empirical spectrum function similar to that described above. A directivity index and an excess attenuation factor are applied to correct for directionality of the sound source and molecular absorption of the acoustic energy by the atmosphere, respectively. Both directivity index and attenuation factors were evaluated from Saturn static tests.

Attempts to compare these predictions with acoustic data from large solid rocket motor tests were not fruitful because of differing test conditions and insufficient data.

The estimated far field acoustic environment on the ground when the vehicle with eight SRM's is at an altitude of approximately 500 to 1000 feet above the launch pad is shown in Figure 7.1.3.0-3.

The following is the damage personnel may experience when exposed to high intensity noise:

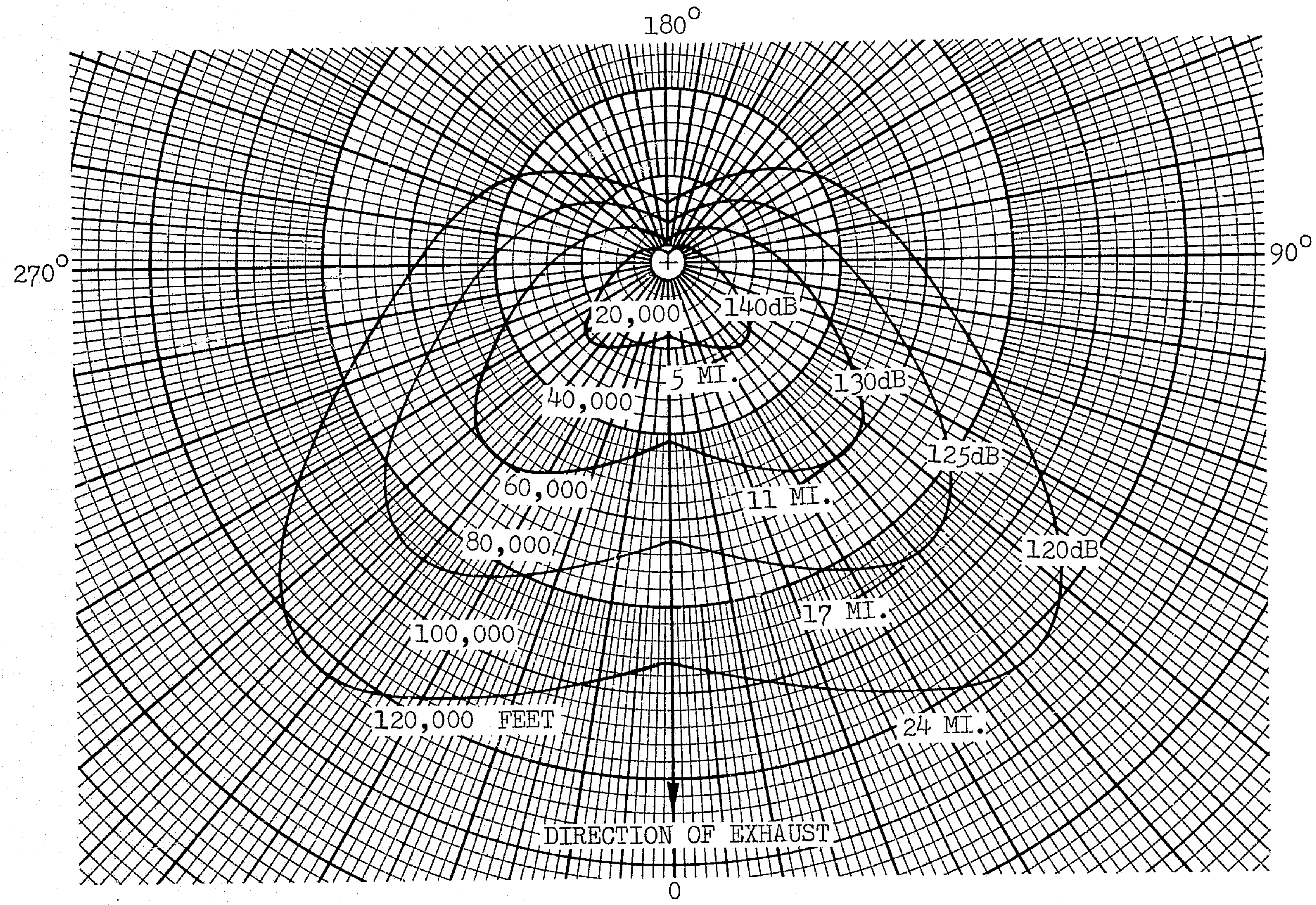


FIGURE 7.1.3.0-1 HALF SIZE MLLV WITH EIGHT 260 INCH SRM, FAR FIELD OASPL "TOPOGRAPHY" ZERO STAGING, VEHICLE ON PAD, SINGLE BUCKET EXHAUST DEFLECTOR

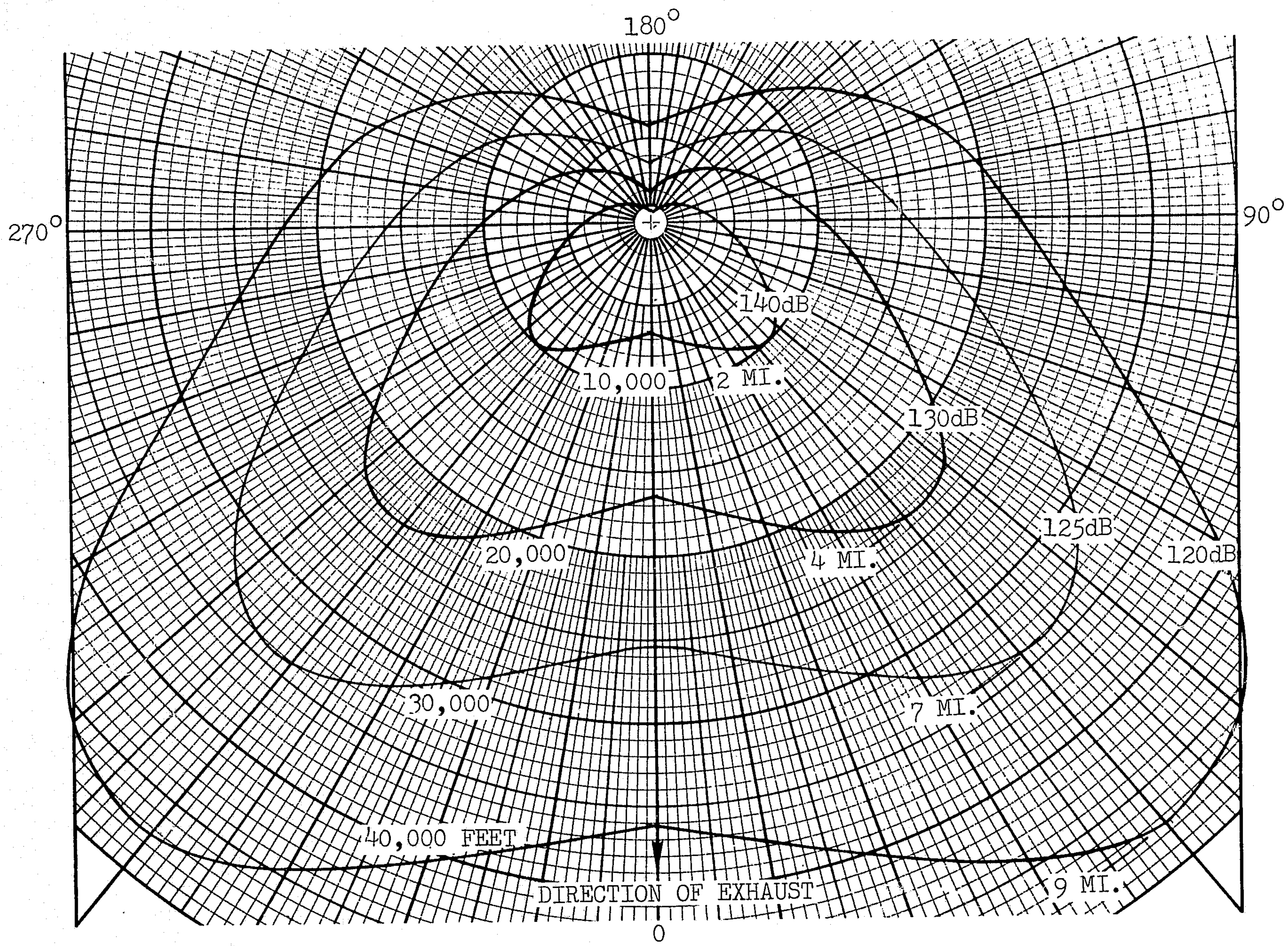


FIGURE 7.1.3.0-2 SINGLE STAGE TO ORBIT MLLV FAR FIELD OASPL "TOPOGRAPHY" VEHICLE ON PAD, SINGLE BUCKET EXHAUST DEFLECTION

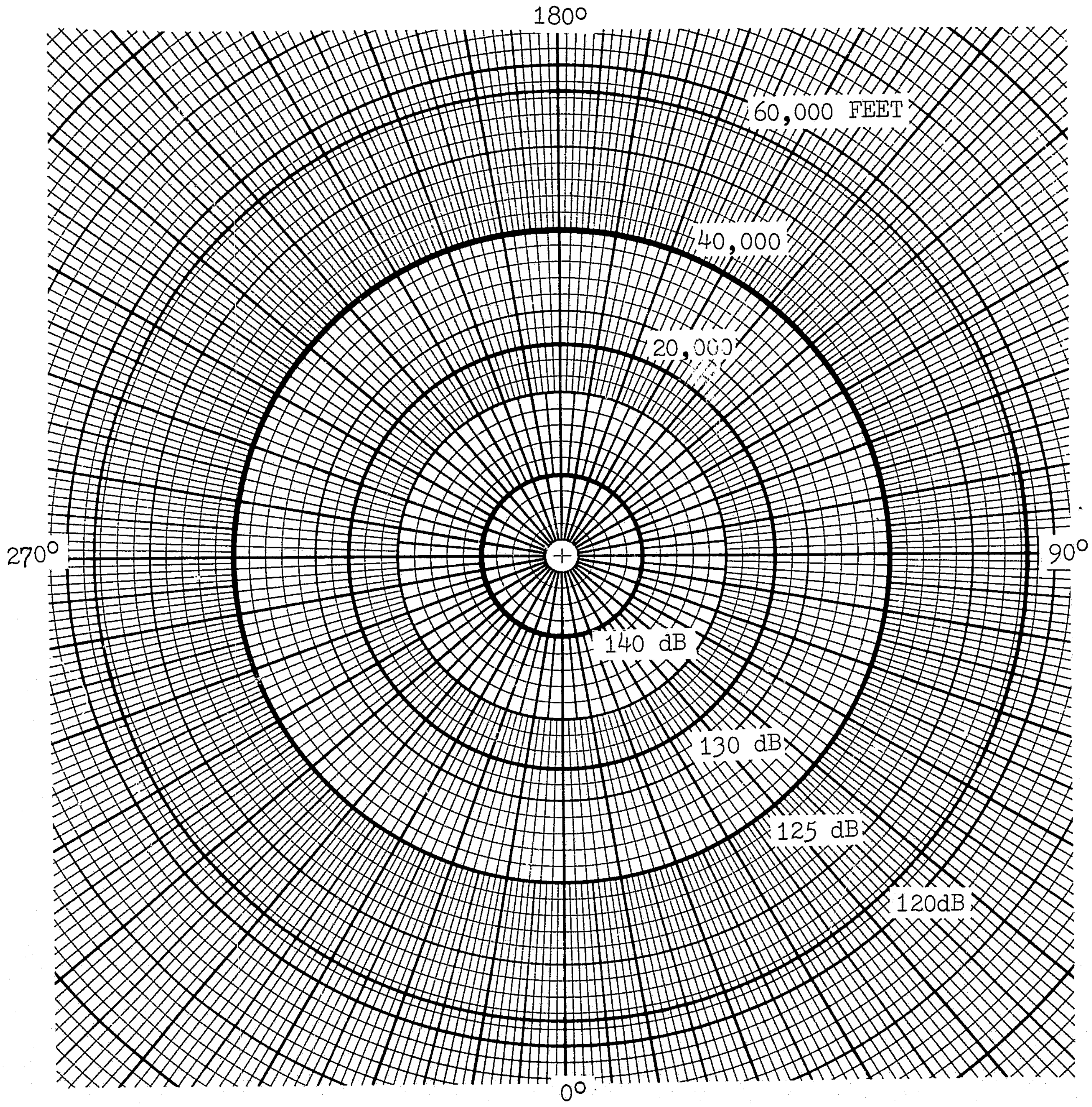


FIGURE 7.1.3.0-3 HALF SIZE MLLV WITH EIGHT 260 INCH SRMS, FAR FIELD OASPL TOPOGRAPHY ZERO STAGING, LAUNCH VEHICLE ALTITUDE 500 TO 1000 FT.

7.1.3 (Continued)

An overall sound pressure level of 120 db produces temporary hearing impairment after prolonged exposure. The threshold of discomfort is approximately 130 db which can cause permanent hearing damage after prolonged exposure (days). The threshold of pain is about 149 db where permanent damage to hearing may occur. Higher noise levels can damage internal organs.

A determination of the acoustics on launch site requirements was made for the MLLV vehicle and compared to the full-size AMLLV vehicle (Figure 7.1.3.0-4). As a siting criteria, the 120 db level was not permitted to reach the Indian River or the nearby town of Titusville. Using existing NASA sites would exceed this limit; therefore, off-shore launch sites were considered necessary as were required for the AMLLV vehicles. The 0.4 psi overpressure design limit is 3.4 miles for the MLLV versus 4.25 miles for the AMLLV. The 120 db line represents a line matching the Indian River side of Merritt Island. The launch must be located to the right (ocean side) of this line to prevent the sound pressure level from exceeding the 120 db limit. This shows that there is no land location near the present NASA site that will not exceed the limit for either the AMLLV or the MLLV maximum vehicle family. The 120 db time as illustrated in Figure 7.1.3.0-4 which falls just short of Titusville represents the sound level generated by 43M pounds of thrust. This is for the maximum configuration vehicle which could be launched from a land based location without impacting Titusville; the AMLLV with four SRM stages, or the MLLV with six SRM stages.

7.1.4 Launch Facility Schedule and Launch Facility Flow Plan

Figure 7.1.4.0-1 shows that the launch facility will be completed by the end of the sixth year, and it is then ready for preparation for the first Research and Development (R&D) flight. After completion of the static firing, refurbishment, vehicle stacking and test checkout, the first R&D flight can be scheduled for the end of the eighth year.

7.2 OVERALL OPERATIONAL SEQUENCE PLAN

This section of the Launch Facility and Operational Sequence Plan presents AMLLV and MLLV launch sequence plans, showing different facets of basically similar launch operations. Detailed sequential flow plans are included. They are broken down to the level necessary for man loading and scheduling. Figure 7.1.4.0-2 is a master flow diagram for launch complex activities. Each block is detailed in subordinate tables contained in Paragraph 7.3.

The launch plans developed for the full size AMLLV and the half size MLLV are similar in every respect. Presented here is the launch plan for the full size vehicle (AMLLV), with discussion and calculations on the sizing of the

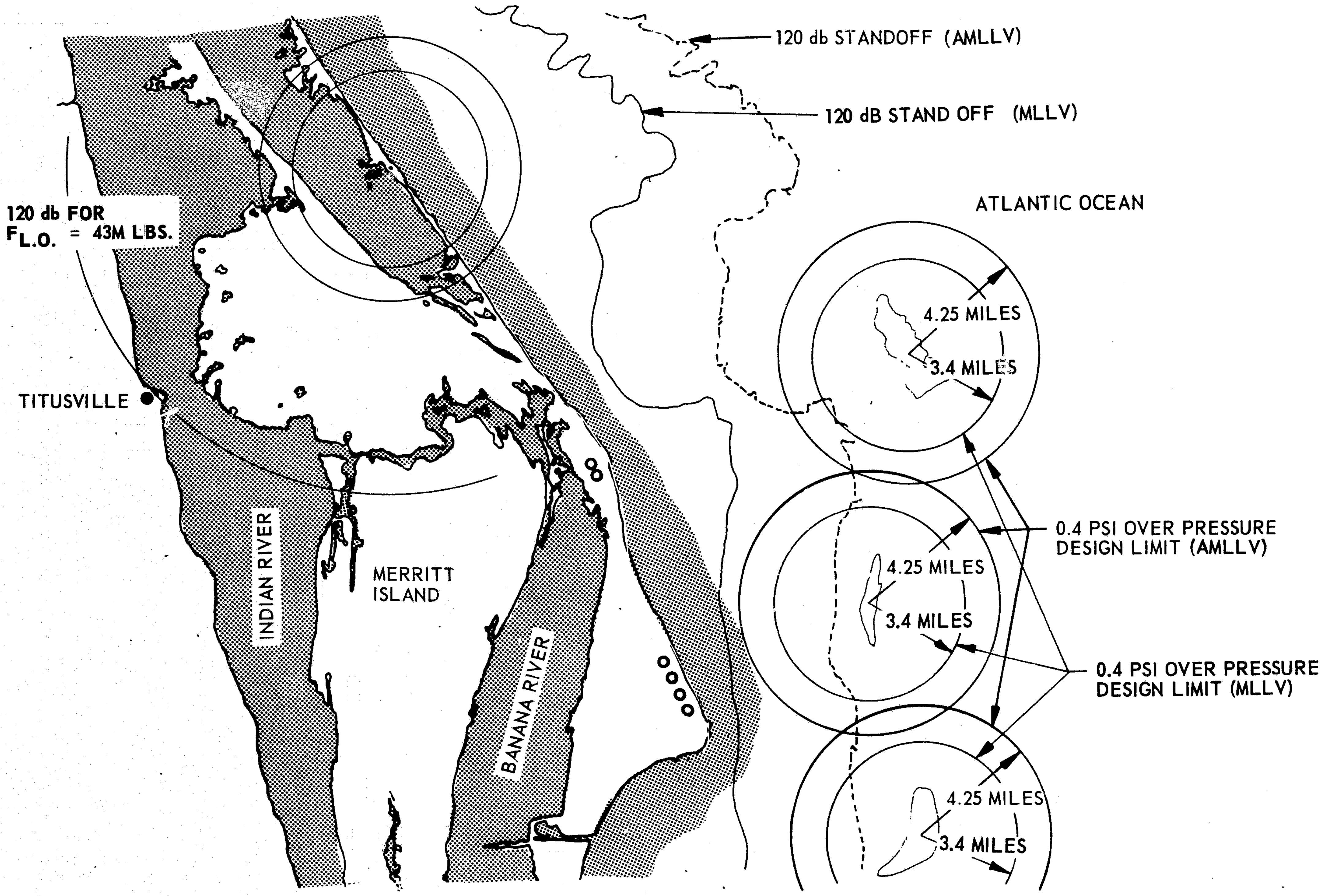
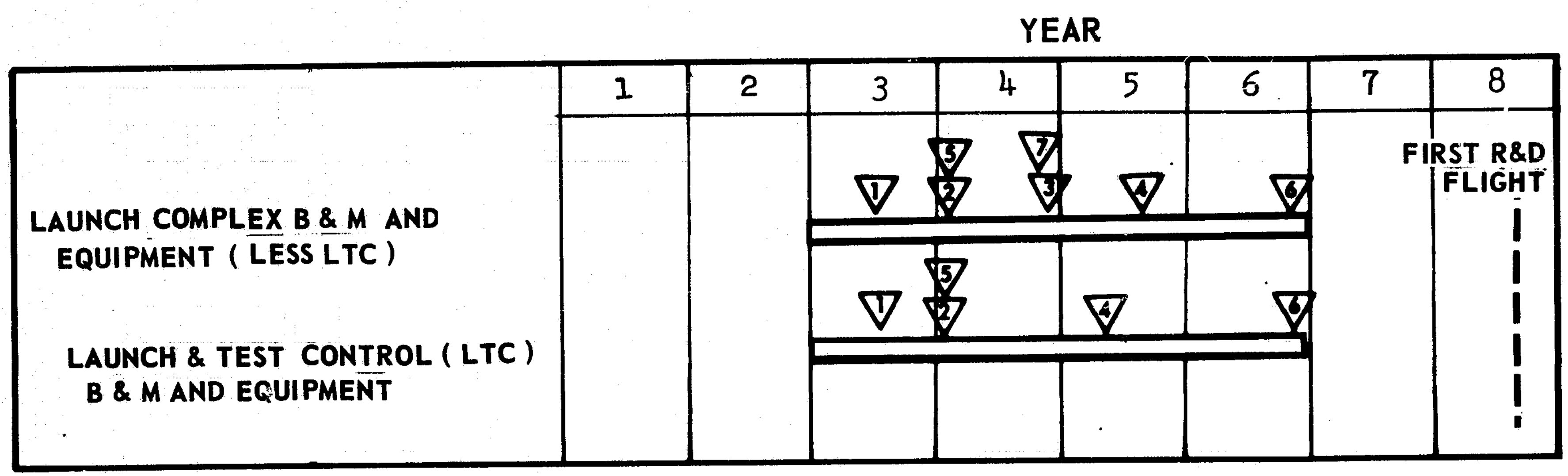


FIGURE 7.1.3.0-4 COMPARISON OF AMLLV AND MLLV SITING REQUIREMENTS



(1) DESIGN CRITERIA COMPLETE

(2) DESIGN 30% COMPLETE CONSTRUCTION START

(3) DESIGN COMPLETE

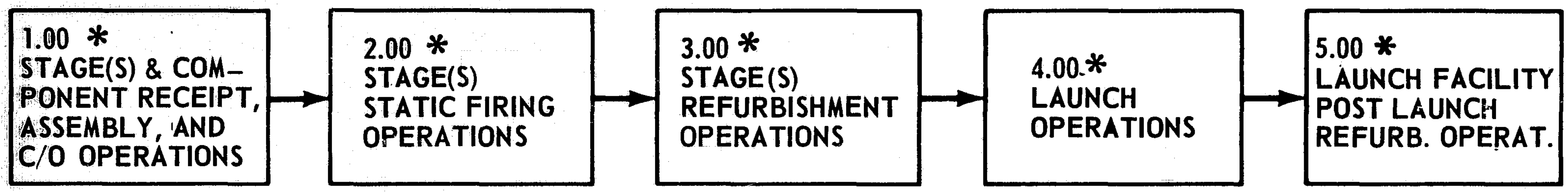
(4) CONSTRUCTION COMPLETE

(5) LONG LEAD EQUIPMENT IDENTIFIED AND ORDERED

(6) EQUIPMENT INSTALLED

(7) STANDARD EQUIPMENT ORDERED

FIGURE 7.1.4.0-1 . LAUNCH FACILITY, BRICK AND MORTAR AND EQUIPMENT



* NUMBERS REFER TO CODE NUMBER SHOWN IN TABLE 7.3.3.0-1.

FIGURE 7.1.4.0-2 LAUNCH COMPLEX ACTIVITIES FLOW PLAN

7.2 (Continued)

launch pad and launch facilities (Figure 7.2.0.0-1). Presented in Paragraph 7.3 under Resource Implications is a further discussion on launch considerations for the half size vehicle (MLLV).

The launch concept for the AMLLV which follows makes comparison with the MLLV requirements. It discusses the handling of the stages, the operation of the lifting devices, and of the gantry. It discusses also vehicle assembly and launch. Figures 7.2.0.0-2 through 7.2.0.0-5 protray the sequential operations flow plans. The code numbers shown on these figures relate the flow plans shown in Figures 7.2.0.0-2 through 7.2.0.0-5 to the facilities and equipment requirements list shown in Table 7.3.3.0-I.

It will be noted that, while the AMLLV launch concept does not specifically cover static firing of the core stage and the injection stage on the pad, this activity is fully documented in the sequential operations flow plan and in the sub-operation sheets following. Static firing, refurbishment, and final vehicle assembly, checkout and launch will all be accomplished at the launch facility. SRM stages will not be off-loaded from the barges until static firing of all vehicle stages is completed.

A countdown demonstration test (CDDT) will be conducted prior to each vehicle launch until all vehicle components are fully man-rated.

7.2.1 Assembly and Launch Sequence

The launch concepts for both the full size (AMLLV) and the half size (MLLV) vehicles must be tailored around the methods for transportation and handling the 260-inch SRM stages.

During the referenced AMLLV study, the launch concept was not identified in enough detail to allow costing to the desired level for this study. Thus, the following concept was detailed for the full size vehicle. It is also applicable to the half size (MLLV) vehicle with relatively small changes. For example, 1) the lifting capacity of the hoist mechanism would be slightly smaller, 2) the size of the launch hole and flame exhaust flumes would be reduced, and 3) the number of SRM positions would be reduced from 12 to 8.

The operational vehicle assembly and launch sequence will be as follows:

a. Each SRM will be assembled into a stage and will be checked out as a stage prior to arrival at the launch pad. It will arrive at the final assembly and launch complex aboard a barge. The barge will be moved to the unloading slip and ballasted down onto caissons;

b. The unloading hoist frame will be lowered and attached to the horizontal trunnion pins (fore and aft) of the SRM stage. (Lifting of the SRM's in this frame and in subsequent operations will be accomplished with

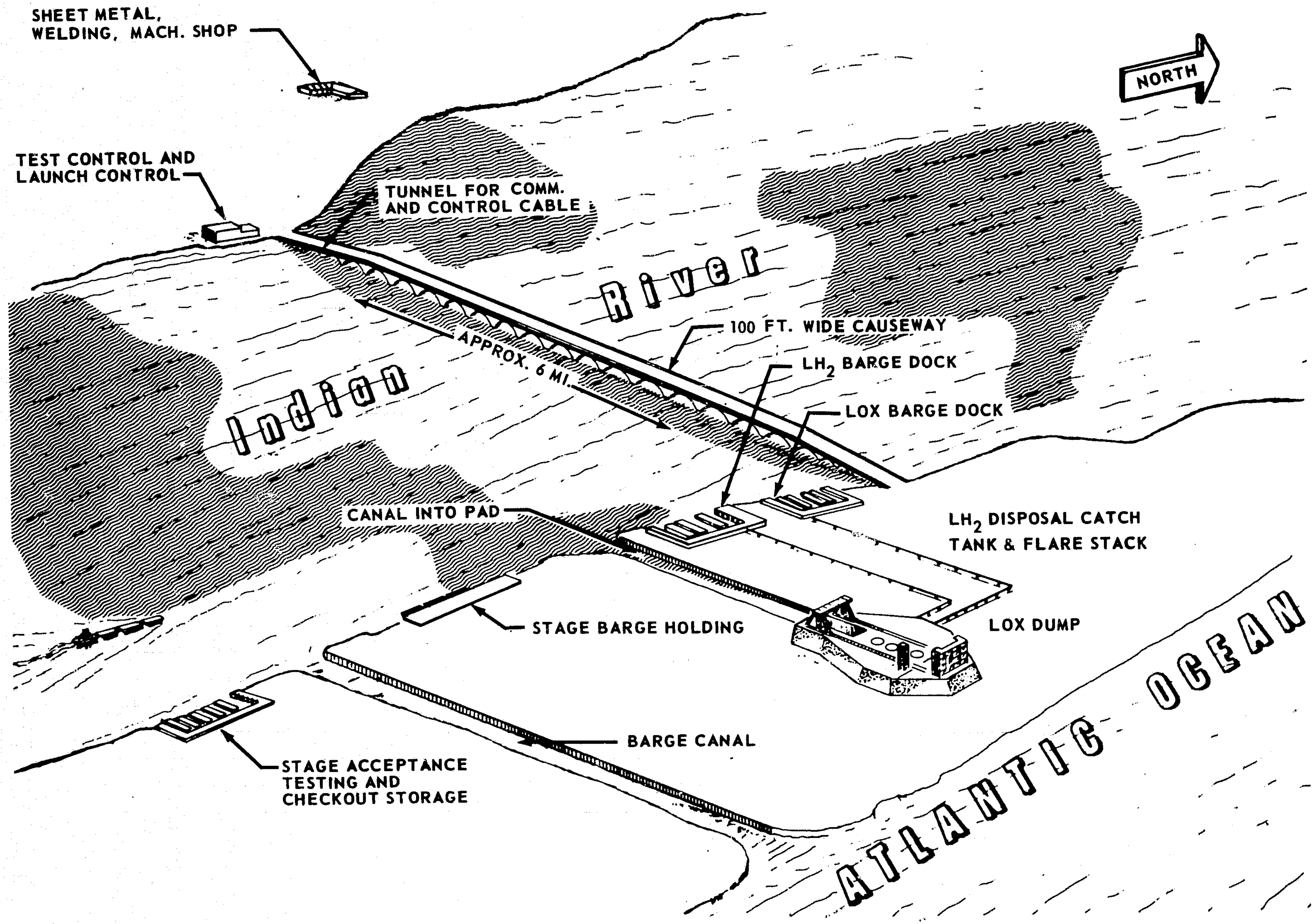


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FIGURE 7.2.0.0-1 AMLLV AND MLLV GENERAL FACILITY LAYOUT

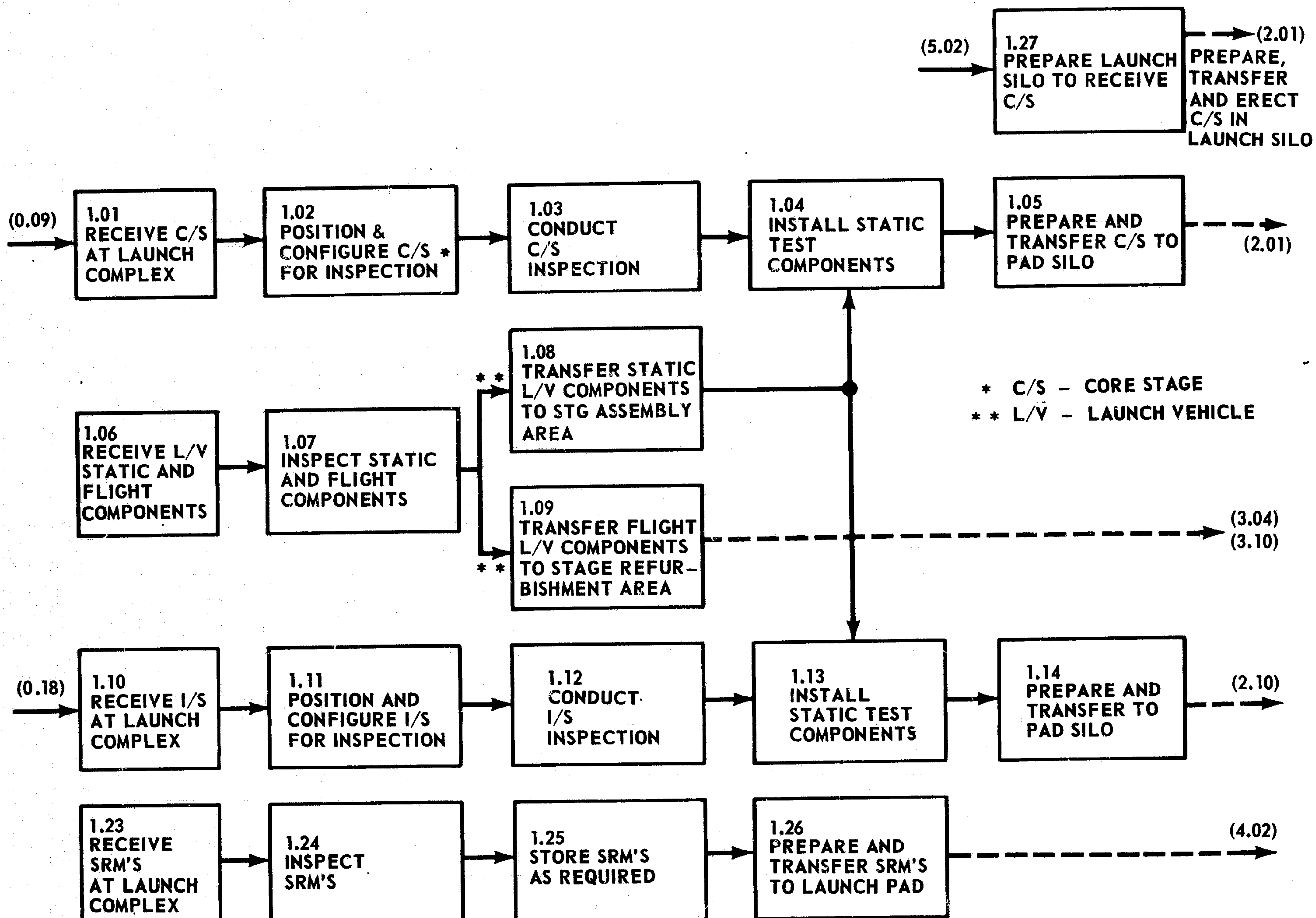


FIGURE 7.2.0.0-2 FLOW CHART NO. 1 – LAUNCH COMPLEX ACTIVITIES

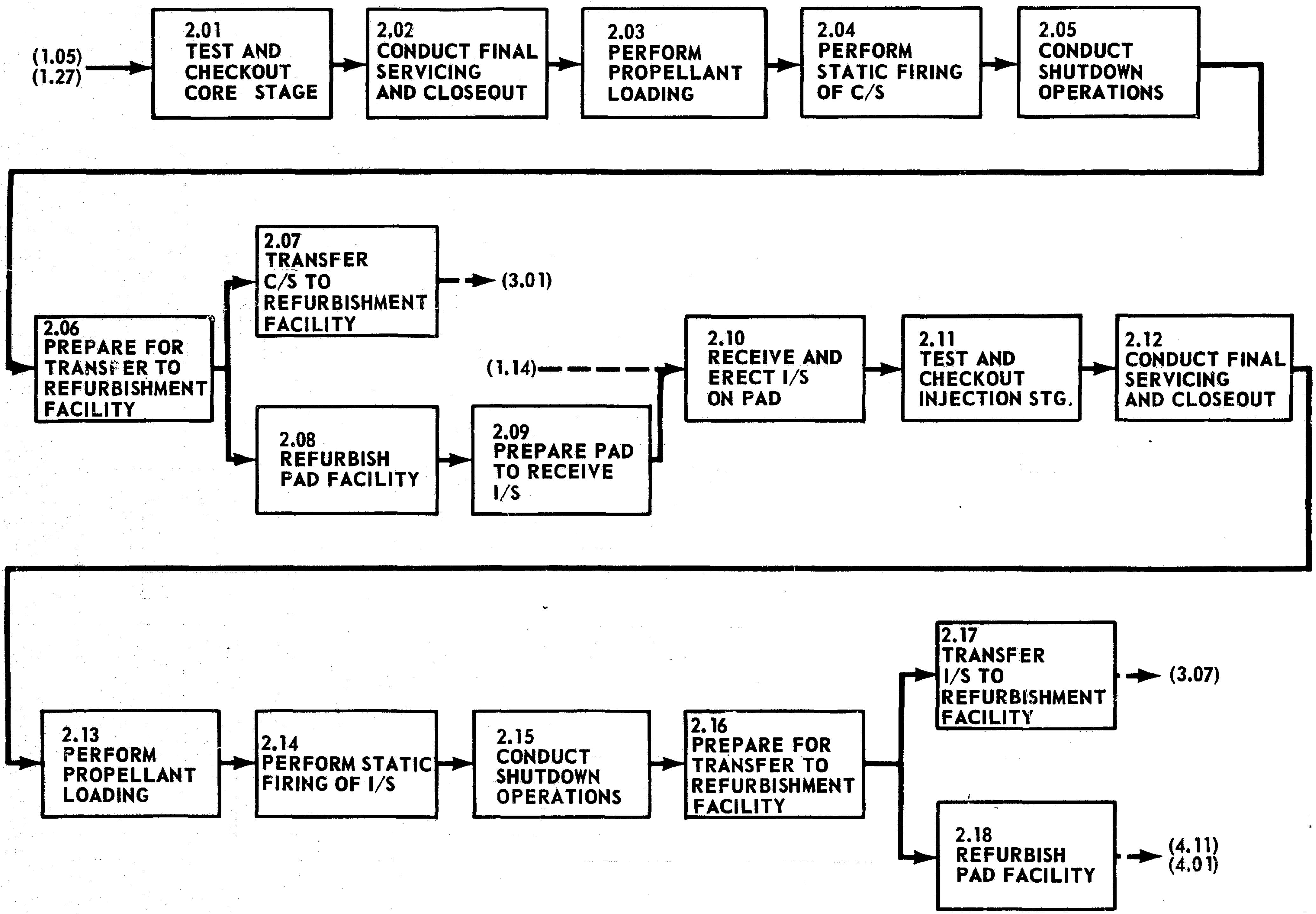


FIGURE 7.2.0.0-3 FLOW CHART NO. 2 - LAUNCH COMPLEX ACTIVITIES

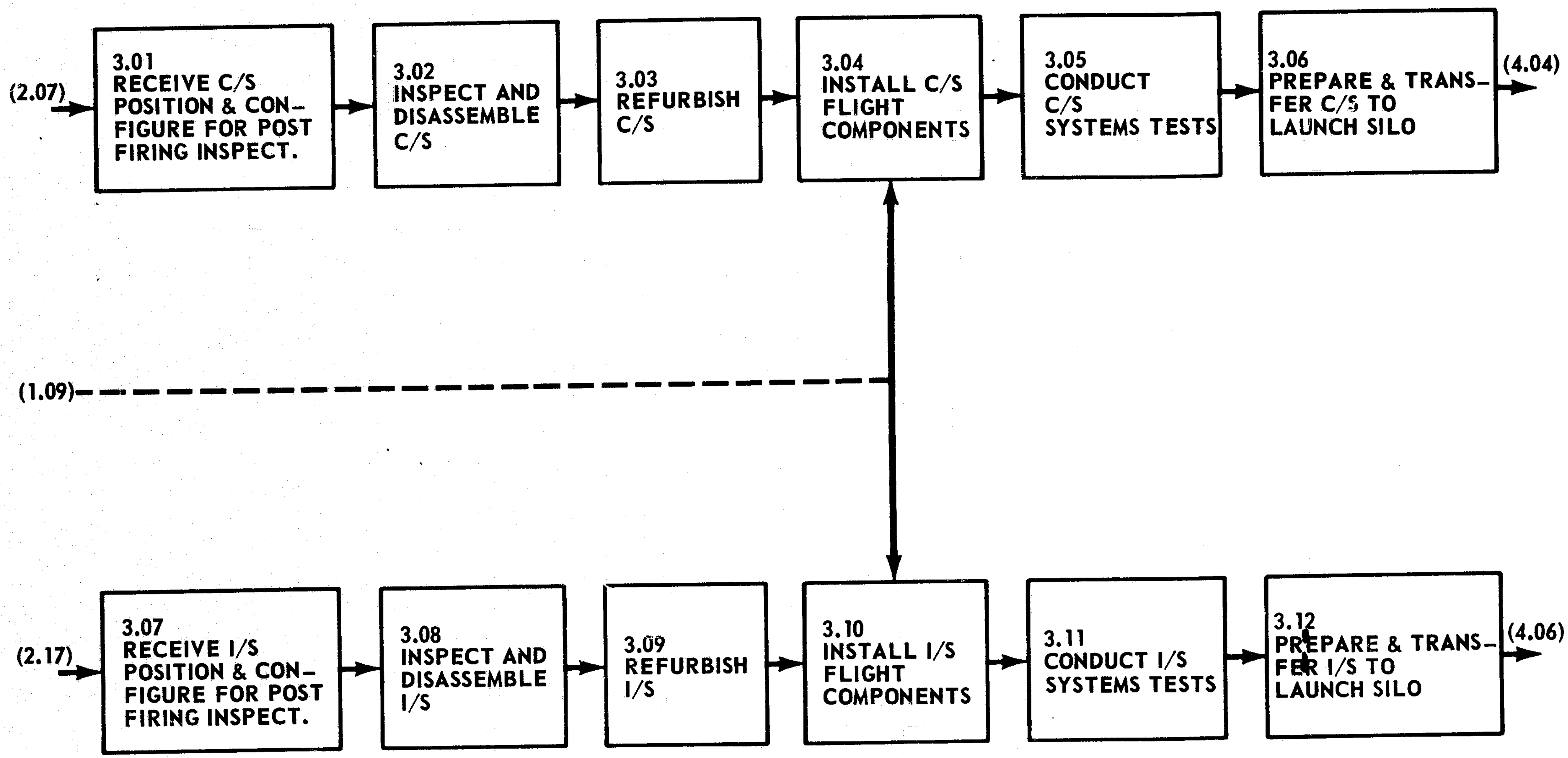


FIGURE 7.2.0.0-4 FLOW CHART NO. 3 - LAUNCH COMPLEX ACTIVITIES

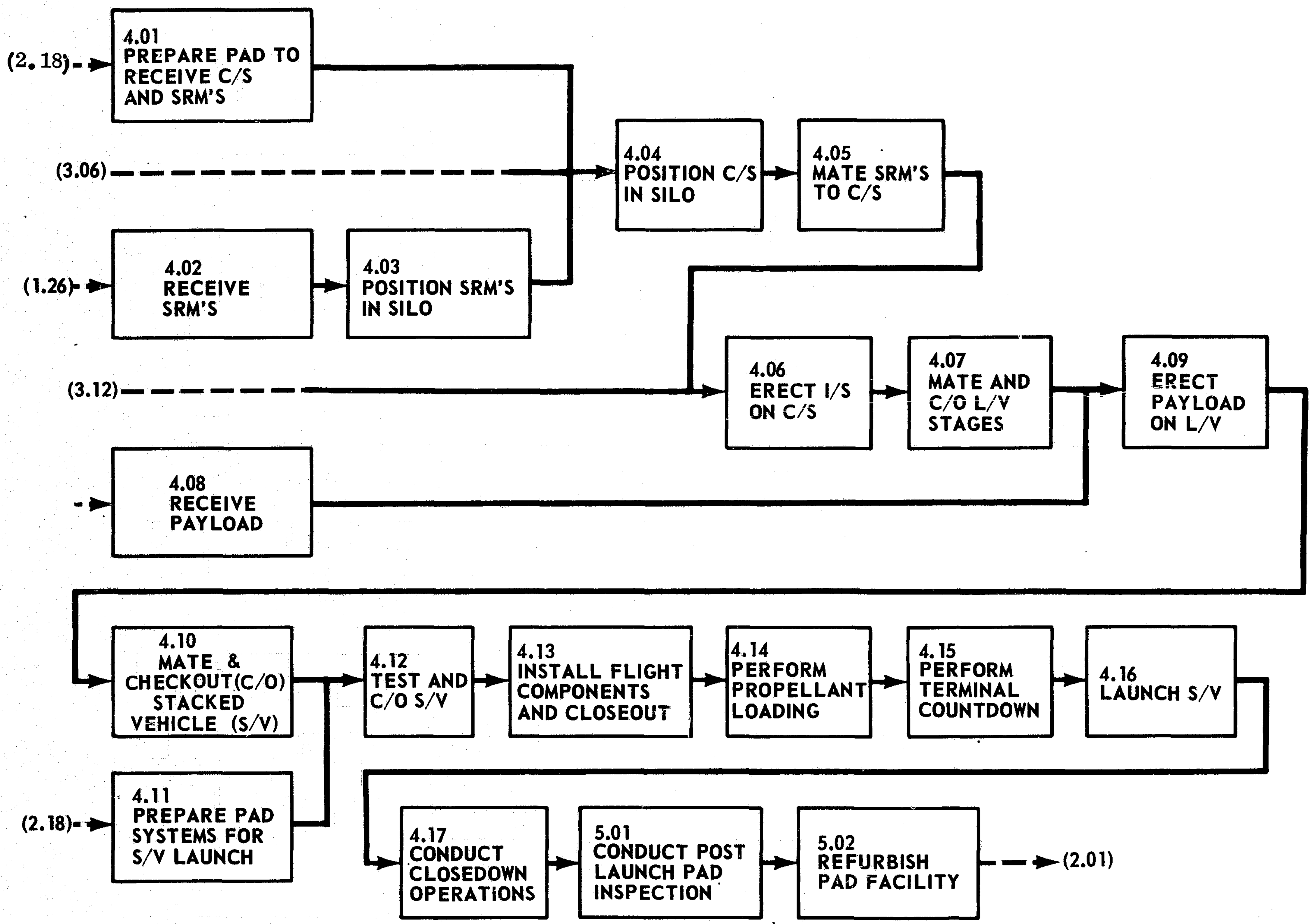


FIGURE 7.2.0.0-5   FLOW CHART NO. 4 - LAUNCH COMPLEX ACTIVITIES

7.2.1 (Continued)

"Roll Ramp Actuators." Costs of these units were obtained from the manufacturer, The Philadelphia Gear Corporation, who produced the 1,500,000 pound load actuators used by NASA in Huntsville, Alabama. Four of these actuators were combined to apply a 6,000,000 pound load to rocket casings.

c. The SRM stage will then be raised to the level of the launch pad deck;

d. The removable unloading hoist frame will be attached to the gantry crosshead;

e. The gantry crosshead will be raised enough so the SRM stage trunnions can be placed in the stage rotating fixture;

f. The gantry crane will be moved to the end of the unloading slip and the crosshead lowered to place the SRM stage in the rotating fixture;

g. The SRM stage will be disconnected from the unloading hoist frame. The frame will be replaced on the unloading hoist using the gantry crane;

h. The gantry crosshead will be attached to the forward SRM stage trunnion. Raising of the crosshead and moving the gantry will rotate the stage into an upright attitude, nozzle end down;

i. The SRM stage will be moved to its vehicle location by the gantry and lowered onto the SRM stage support and alignment fixture;

j. Braces to the forward end of the SRM stage will then be attached. The gantry will be moved away, and the alignment fixture moved so that the stage is adjacent to the silo wall. The preceding steps "a" through "j" will be repeated for each SRM strap-on stage used on the launch vehicle;

k. The main stage will be brought to the assembly and launch complex in a horizontal position by barge from KSC. The stage will have been checked-out prior to departure for the launch site.

l. The main stage will be unloaded from its barge using a cable hoist mounted on the crosshead of the gantry. The stage will be rotated in the air and moved to the launch position and inserted in the silo;

m. The core will be lowered into position onto support arms by use of the gantry crosshead cable hoist;

7.2.1 (Continued)

n. Each SRM stage will be aligned and mated to the core stage. The core in the final launch position is supported by the SRM's. The support arms from the silo wall to the core will be removed to transfer support to the SRM stages;

o. The payload and injection stages will be joined together, after having been removed from their barges, prior to placing them on the core stage;

p. As a single unit, they will be picked up by the gantry and placed on the vehicle stack;

q. After joining the injection stage/payload assembly to the core, the service structure will be moved to the vehicle for check-out, arming and servicing;

r. The service structure will be removed just before the vehicle is launched;

s. The vehicle will then be launched. Flame deflectors will be provided at the vehicle base to reduce launch pad damage;

t. Refurbishment of the launch complex will complete the cycle.

7.2.2 Launch Facility Sizing

To develop resources and costs for the AMLLV and MLLV, the launch facility was sized. Although the acoustics and explosive hazard criteria necessitate an off shore location, an on shore site was ground ruled to obtain creditability for launch resources and costs. Siting and sizing criteria are discussed below and in Paragraph 7.3.6, which discusses the possible use of a modified Launch Complex No. 39 for launch of AMLLV and MLLV vehicles without strap-ons.

7.2.2.1 Siting

Consideration was given to explosive hazards, acoustics, soil bearing allowables, accessibility for barge transportation and possibility of utilization of existing launch support facilities when various sites were investigated for the full size and half size vehicle launch pads. It is obvious that picking a firm location would require time and manpower expenditures far beyond those allowable in this study. It has, therefore, been ground ruled that the launch complex to be costed will be at KSC on the shore line a short distance north of LC-39.

The preliminary far field acoustic situation for this site is summarized along with the explosive hazard predictions in Figures 7.2.2.1-1 and 7.2.2.1-2. Two concepts for the half size vehicle exhaust flumes were considered. The first concept had three flumes and the second concept a single flume. The single bucket is the concept selected for this study.

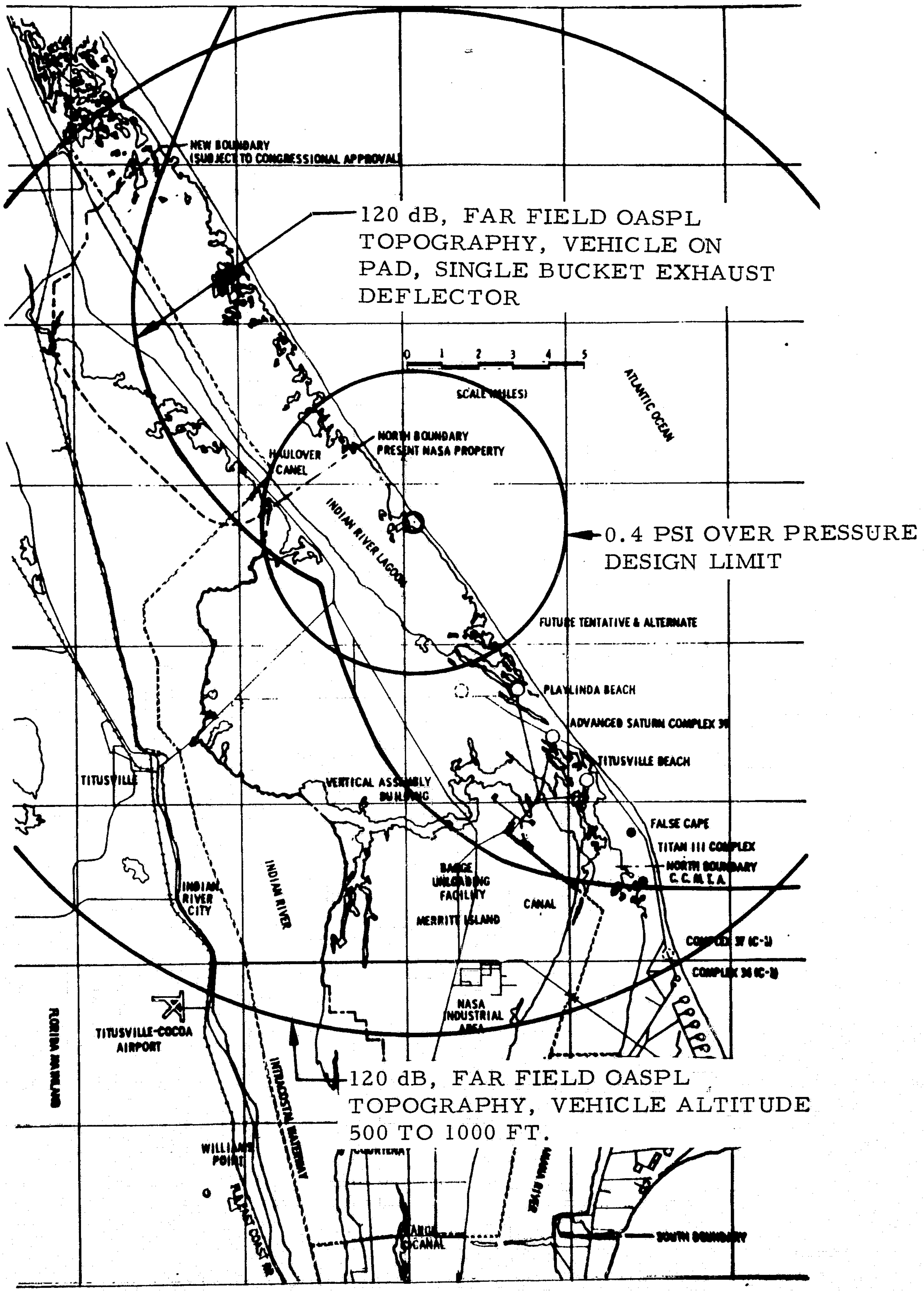


FIGURE 7.2.2.1-1 FULL SIZE AMLLV SITING SUMMARY - (ACOUSTIC AND EXPLOSIVE HAZARD)

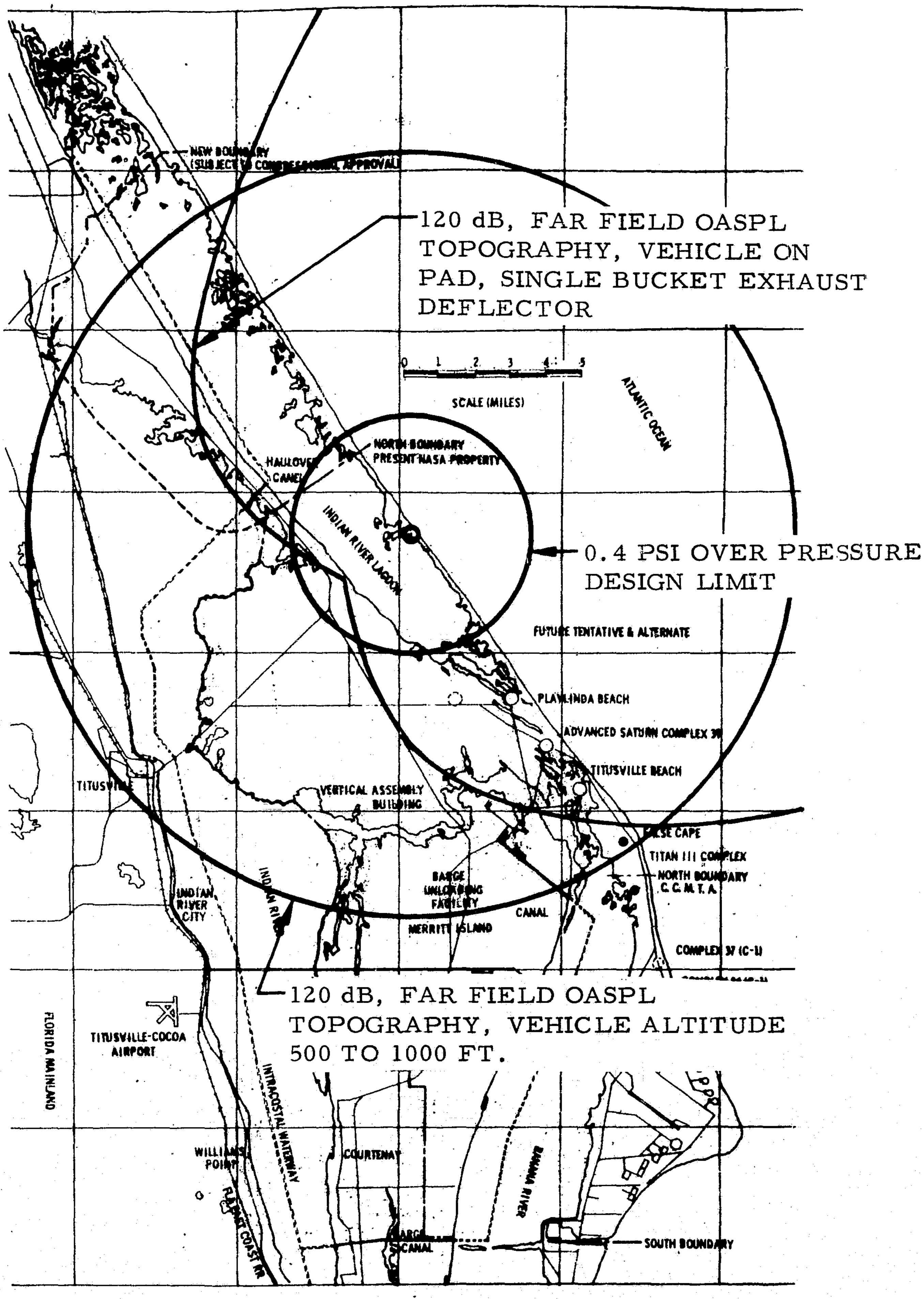


FIGURE 7.2.2.1-2 HALF SIZE MLLV SITING SUMMARY - (ACOUSTIC AND EXPLOSIVE HAZARD)

7.2.2.1 (Continued)

Due to the size and weight of the launch pad, a problem exists in the area of soil mechanics. Dry land bearing allowables at KSC are 1500 to 2000 pounds per square foot. The concept as presented results in a load that is an order of magnitude greater than the allowable. The alternate methods of solving this problem are 1) increasing the footing area, 2) stabilizing the soil or 3) designing the pad as a partially buoyant structure. It is assumed in this cost study that the pad structure is monolithic and partially buoyant.

7.2.2.2 Sizing of the Launch Pad and Launch Equipment

In order to describe the launch pad and associated equipment in more detail, it was necessary to establish certain key dimensions. The following paragraphs describe these dimensions and their derivation.

a. Silo Hole Diameter - From the prior AMLLV study, it was determined that 12 1/2 ft. clearance between the silo wall and the SRM stage would be required considering possible drift angle.

		AMLLV	MLLV
1.	Core vehicle	72'	57'
2.	2-260" SRM's Stages	44'	44'
3.	Core/SRM clearance	4'	4'
4.	SRM/wall clearance	25'	25'
5.	Required silo diameter	145'	130'

b. Maximum Lift Height Required - This is defined as the distance between the deck and the bottom of the crosshead. It was determined that the requirement to stack the payload and injection stage on top of the main stage would require the greatest lift height. The SRM nose cone height, when the SRM is in position for launch, is 63 feet above the deck (assuming that the forward attachment plane is approximately 25 feet above the deck). The payload plus injection stage (maximum size vehicle) will be 285 feet long. A clearance allowance between injection stage bottom and SRM nose cone of 6 ft. was allowed. Thirty-six feet was allowed for sling clearance between the payload and crosshead. The required distance between the deck and the bottom of the crosshead is the sum of these distances and is equal to 390 feet for the AMLLV maximum vehicle configuration. A similar analysis of the MLLV maximum vehicle configuration indicates a distance of 300 feet is required.

7.2.2.2 (Continued)

c. Unloading Hoist - The unloading hoist to lift the SRM stage from the barge to the pad deck will use "Roll Ramp Actuators".

d. SRM Support and Alignment Fixture - The requirements that the SRM stages may be used in various combinations from zero to a maximum of twelve for the AMLLV (eight SRM stages for the MLLV) and that they must be mated to the core stage without putting any significant loads into the core dictated the design. "Roll Ramp Actuators" will be used as the final alignment adjusters. The power mechanisms for moving the SRM stage and alignment fixture in a radial direction and for rotating the stage on the fixture have not yet been determined. No problems are expected, because the required motions can be made at a slow rate.

e. SRM to Deck Brace - These braces will be attached before the gantry is disconnected from the stage and will be removed after the stage is mated to the core.

f. Exhaust Gas Flume and Flame Deflector - The exhaust gas flume and flame deflector were sized by using a S-IC/AMLLV thrust ratio and the diameter measurement at the engine exit plane. A more reasonable sizing of the deflector and flume would be obtained if some kind of a gas-volume ratio is used to scale S-IC dimensions. A ratio based on mass flow ($\dot{m}$) is one possible approach and is the one adopted for obtaining the required dimensions. Areas were scaled by $\dot{m}_1/\dot{m}_2$ and linear distances by $(\dot{m}_1/\dot{m}_2)^{1/2}$. $\dot{m}$ is obtained by dividing the stage thrust with the sea-level specific impulse.

   The test lab at MSFC is in the process of conducting a series of model firing tests for KSC. These tests involve firing a 1/58 scale S-IC with 4 scaled 120" SRM attached as strap-ons. The thrust of the hybrid model is increased by approximately 65 percent. The scaled S-IC exhaust disposal provisions adequately handle the combustion products; therefore, it is concluded that the 5400 square foot S-IC exhaust flume is oversized. The exhaust gases could be handled with approximately a 3000 square foot flume.

   The two items to be sized with the mass flow ratios are the radius of curvature of the flame deflector (R) and the cross-sectional area of the exhaust flume (A). Table 7.2.2.2-I summarizes the results of these calculations.

7.3 RESOURCE IMPLICATIONS

Resource implications are cataloged and discussed below. Man-loading of the operations covers all direct labor, including logistics support functions, etc. Time lines covering all launch operations establish a preliminary launch cycle of

TABLE 7.2.2.2-I EXHAUST DISPOSAL PROVISIONS SIZING SUMMARY

STAGE	THRUST (LBS)	Isp (SEC)	$\dot{m}$ (LBS/SEC)	$\left(\frac{\dot{m}\ \text{STAGE}}{\dot{m}\ \text{S-IC}}\right)$	$\left(\frac{\dot{m}\ \text{STAGE}}{\dot{m}\ \text{S-IC}}\right)^{1/2}$	R (FT)	A (SQ FT)
S-IC	7.6M	263	28,517		1	42	3,000
MLLV (8-260" Strap-ons)	54.4M	237	229,536	8	2.83	120	24,000
AMLLV (12-260" Strap-ons)	108.0M	237	455,668	16	4	168	48,000

NOTE:

I_{sp} = Specific Impulse at Sea Level

$\dot{m}$ = Exhaust Mass Flow Rate

R = Radius of Curvature of the Thrust Deflector

A = Cross-Sectional Area of the Exhaust Flume

7.3 (Continued)

32 weeks, which is reduced to 29.5 weeks when launch pad refurbishment activities are conducted concurrent with barge unloading and stage receiving inspection activities. Launch facility drawings and descriptions have been developed to show a launch complex suitable for either the full size (AMLLV) or half size (MLLV) vehicle. GSE and LVGSE lists developed for costing are included.

The resource implications for the Launch Complex are divided into the following categories:

a. Manpower and schedules

b. Materials (Expendable Consumption)

c. Launch Vehicle Ground Support Equipment (LVGSE)

d. Facility Ground Support Equipment (GSE)

e. Facilities

Though on-board test and checkout was specified for the vehicles, the resource requirements for the launch cycle are based on the conventional Saturn V prelaunch test and checkout procedures. Additional study is required to adequately assess the impact of on-board test and checkout systems on all test and checkout procedures.

7.3.1 Manpower and Schedules

7.3.1.1 Contractor Manpower

Contractor headcount required for the first AMLLV (maximum payload vehicle) launch cycle will peak at approximately 16,500. This should decrease to about 14,000 by the third launch cycle and then to approximately 11,000 by the fifth launch cycle. For the MLLV (maximum payload vehicle) these manpower requirements are 15,510, 13,160, 10,340 for the first, third and fifth cycles. Table 7.3.1.0-I shows the Launch Complex manpower requirements per launch cycle.

The direct headcount forecast is divided as follows: 27 percent launch vehicle operations; 11 percent design support; 32 percent technical support consisting of maintenance and operation of major facilities, and operation, maintenance, and installation of instrumentation and communication equipment; and 30 percent for installation support which consists of housekeeping, reproduction, photography, computer services and other general services. The equivalent direct manhours corresponding to the headcount requirements are also shown on Table 7.3.1.0-I. These equivalent manhours were developed assuming a six month launch cycle, a 10% overtime factor for normal operations and a 25% overtime factor for peak operations which will occur during static firing, refurbishment and launch readiness.

TABLE 7.3.1.0-I LAUNCH COMPLEX MANPOWER REQUIREMENTS PER LAUNCH

LAUNCH VEHICLE	LAUNCH COMPLEX PERSONNEL REQUIREMENTS	*C/S, I/S & SRM STAGES		*C/S & I/S STAGES		*C/S ONLY	
		AMLLV	MLLV	AMLLV	MLLV	AMLLV	MLLV
FIRST VEHICLE	HEAD COUNT	16,500	15,510	15,800	14,852	14,000	13,160
	(M/HRS.)	17,751,000	16,685,940	16,997,927	15,978,051	15,061,454	14,157,767
THIRD VEHICLE	HEAD COUNT	14,000	13,160	13,080	12,220	12,800	11,280
	(M/HRS.)	15,061,450	14,157,763	13,985,636	13,146,498	12,909,817	12,135,228
FIFTH VEHICLE	HEAD COUNT	11,000	10,340	10,000	9,400	9,500	8,930
	(M/HRS.)	11,834,000	11,123,960	10,758,181	10,112,690	10,220,272	9,607,056

* C/S - CORE STAGE

* I/S - INJECTION STAGE

* SRM - SOLID ROCKET MOTOR STAGE

NOTE: THESE INPUT REQUIREMENTS (FOR A 6 MONTH LAUNCH CYCLE) WERE USED TO DEVELOP R&D FLIGHT TEST AND OPERATIONAL FLIGHT MANPOWER REQUIREMENTS. THE R&D FLIGHT TEST MANHOURS WERE DEVELOPED FROM THE "FIRST VEHICLE" REQUIREMENTS ADJUSTED FOR A 9 MONTH LAUNCH CYCLE AND SOME INCREASED INSTRUMENTATION. THE OPERATIONAL MANPOWER REQUIREMENTS WERE DEVELOPED ASSUMING THAT LAUNCH MANPOWER WILL BE CONSTANT. A WEIGHTED AVERAGE OF THE "THIRD" AND "FIFTH" VEHICLE MANPOWER WAS USED TO DEFINE THE CONSTANT OPERATIONAL PROGRAM MANPOWER REQUIREMENTS AS FOLLOWS:

$$\frac{2 \text{ X "THIRD" VEHICLE} + 8 \text{ X "FIFTH VEHICLE}}{10} = \text{MANPOWER REQUIREMENTS PER OPERATIONAL LAUNCH}$$

7.3.1.1 (Continued)

Total manhour requirements for one complete AMLLV launch cycle, i.e. from receipt of flight hardware at the launch facility through static firing, refurbishment, checkout and launch is estimated at 17,751,000 manhours. This is exclusive of any NASA manpower. It covers all manpower necessary to receive, process, test and launch the flight vehicles, including supporting manpower.

7.3.1.2 AMLLV/MLLV Launch Operations Schedules

The ground rules for the time lines Figure 7.3.1.2-1 through 7.3.1.2-4 are as follows:

a. All time lines are based on around-the-clock operations (7 day weeks, 3 shifts per day);

b. Both the main stage and injection stages will arrive at KSC fully instrumented and calibrated for static firing. (Installation of stage instrumentation and associated wiring at KSC will add approximately eight weeks time to total flow time);

c. The time lines are based on a single contractor for the launch complex;

d. All gantry crane functions must be accomplished in one shift each;

e. Baseline static firing for both stages include a series of minimum thrust, intermediate thrust and full thrust firings for a total of three firings;

f. The baseline launch vehicle includes twelve SRM's for the full size AMLLV and eight SRM's for the half size MLLV;

g. No times have been built into the time lines for:

   1. Hardware storage,

   2. Contingencies,

   3. Facility activation functions,

   4. Major refurbishment of stage related to the failure of either stage to successfully complete static firing;

h. Other factors considered in the preparation of the time lines are:

   1. Interferences between silo and refurbishment area operations: i.e.,

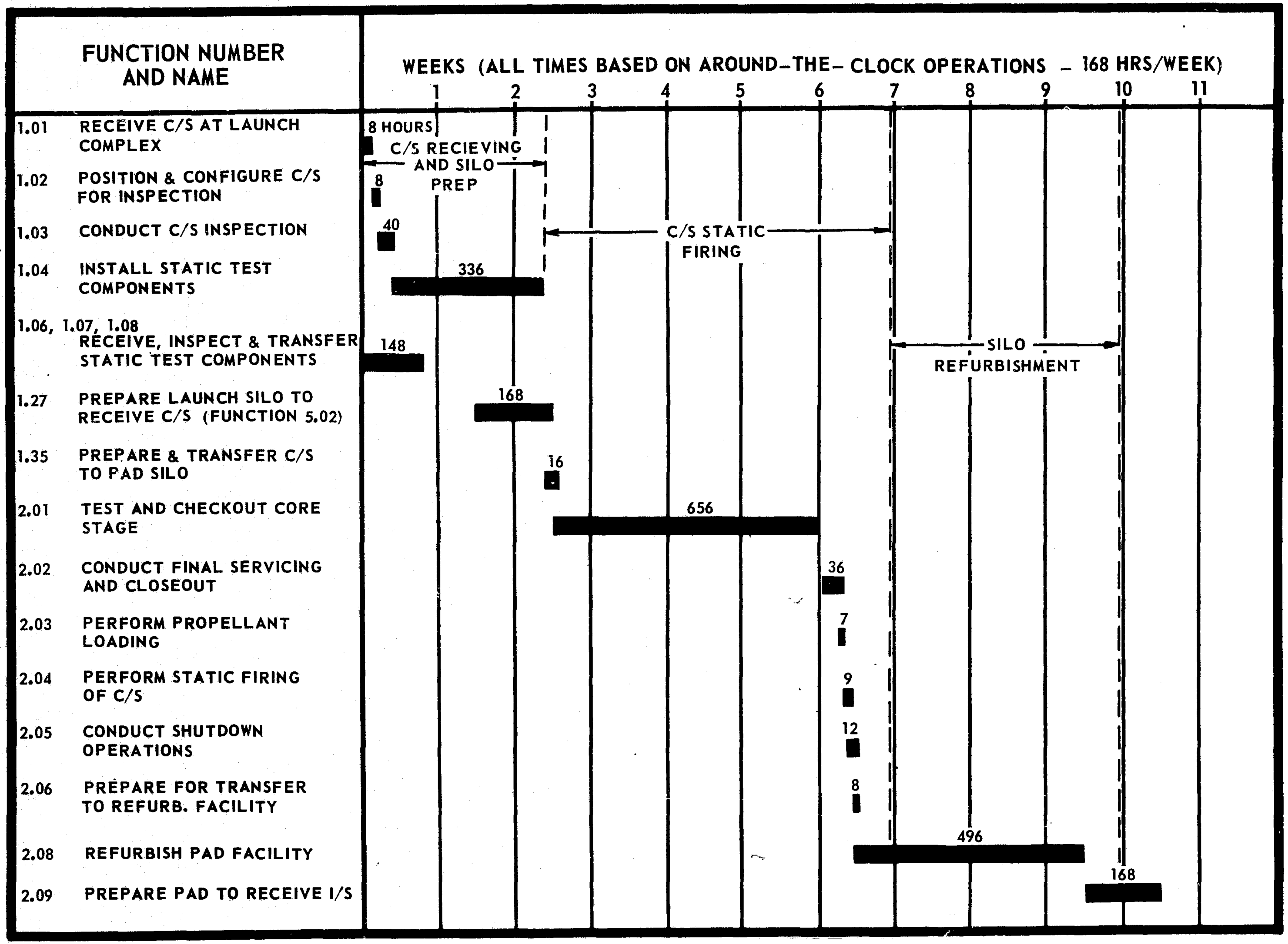
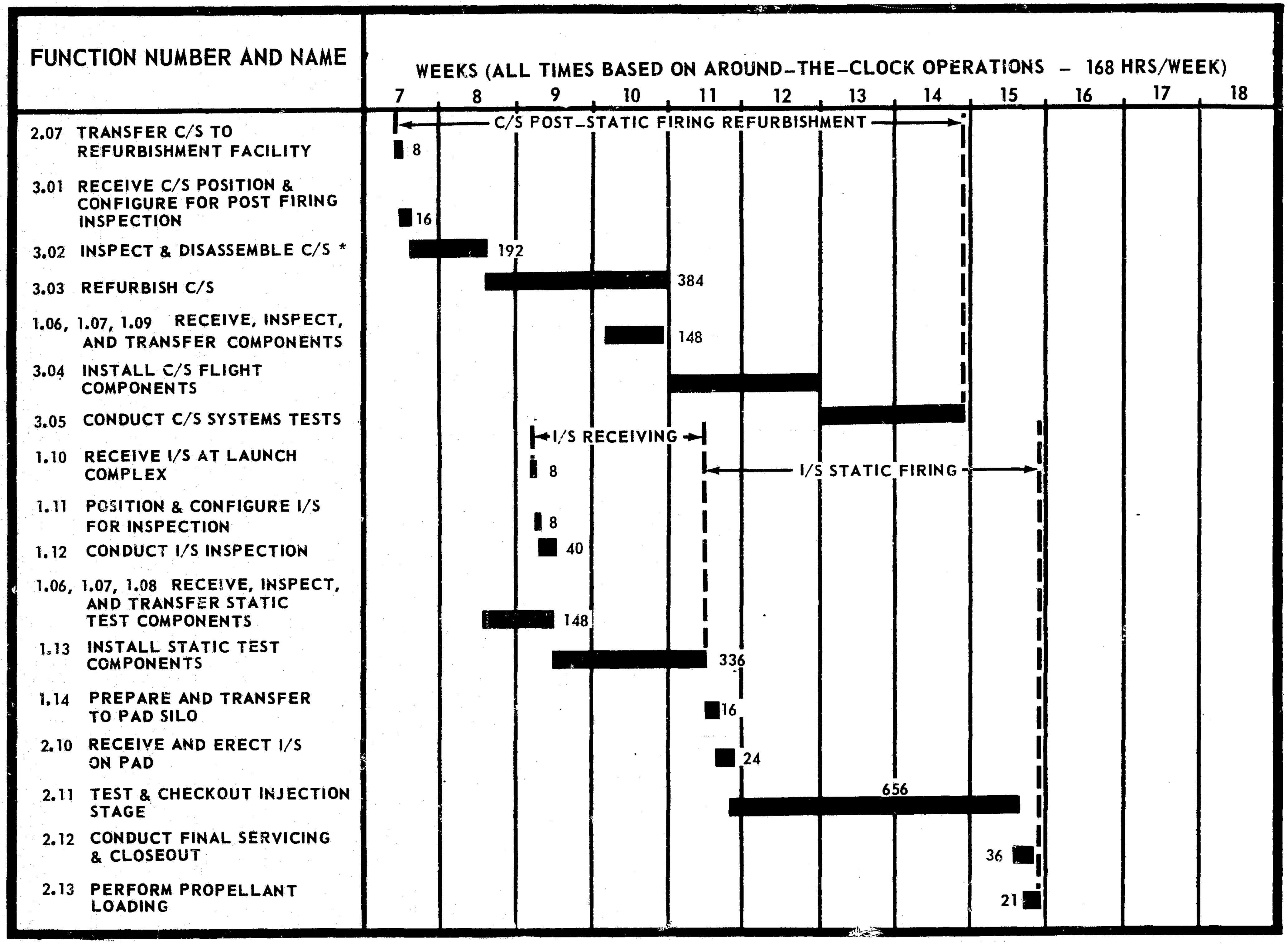
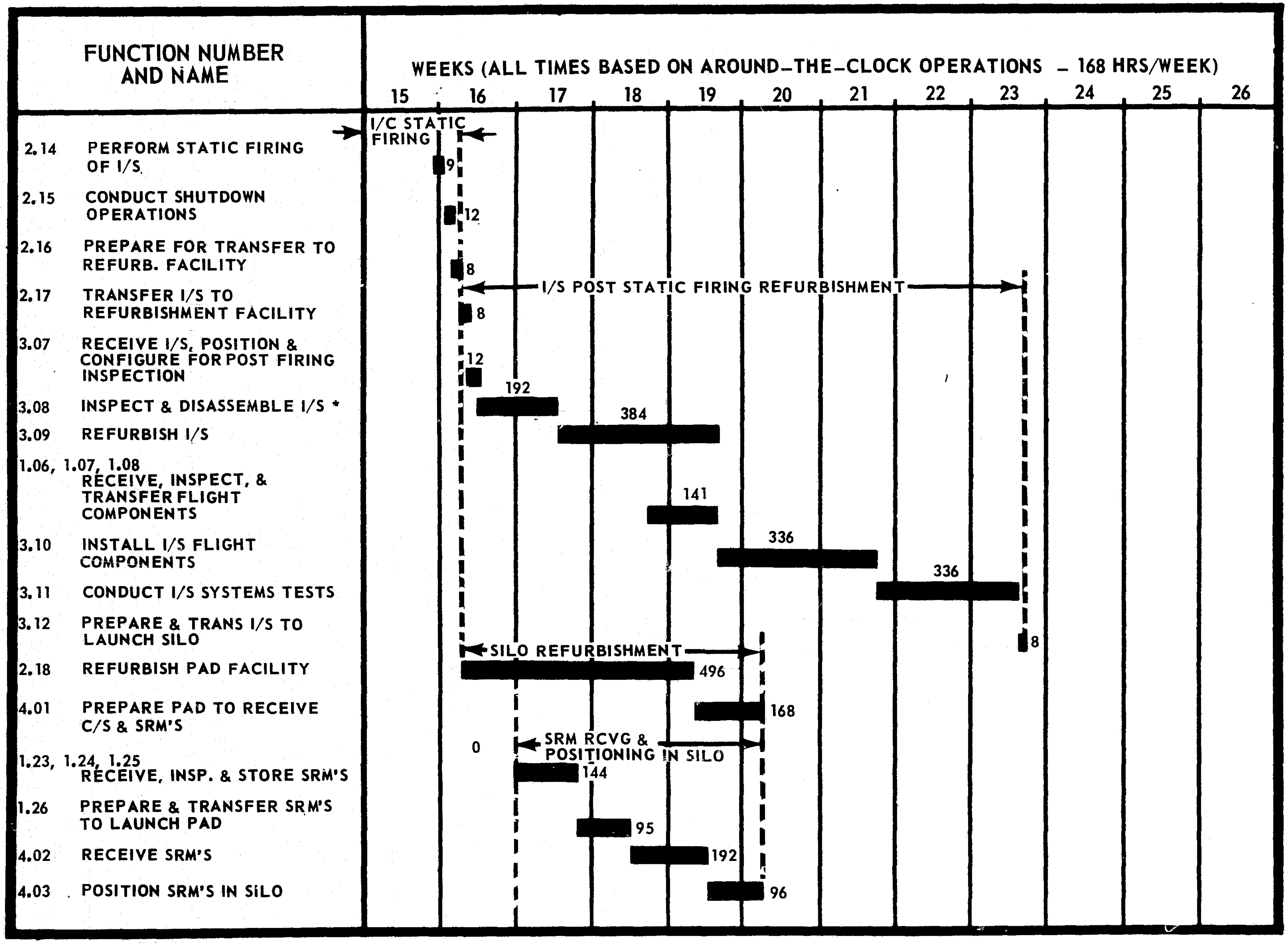


FIGURE 7.3.1.2-1 TIMELINE #1 - LAUNCH SITE OPERATIONS



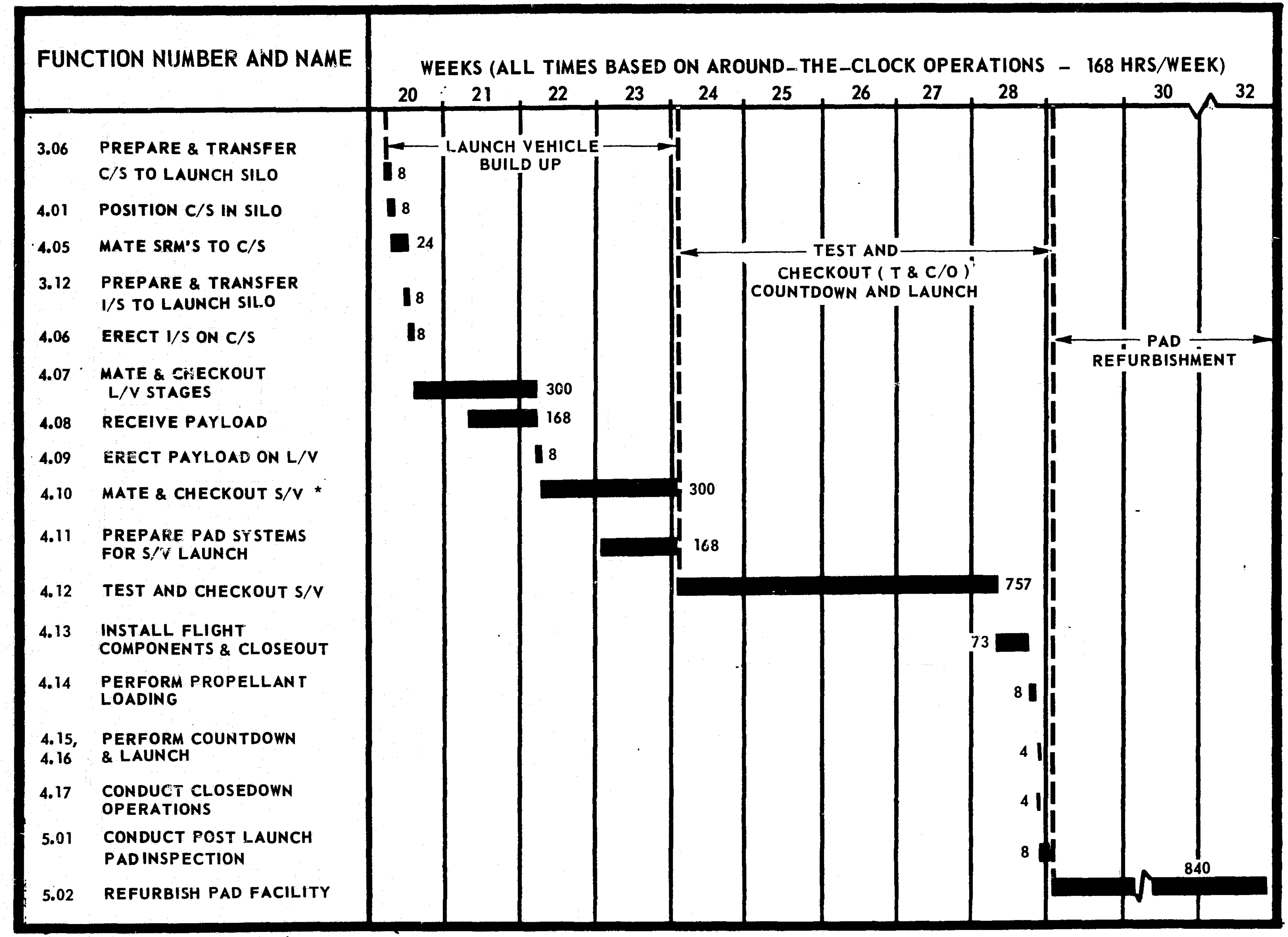
* AS REQUIRED

FIGURE 7.3.1.2-2 TIMELINE #2 - LAUNCH SITE OPERATIONS



* AS REQUIRED

FIGURE 7.3.1.2-3 TIMELINE #3 - LAUNCH SITE OPERATIONS



* SPACE VEHICLE

FIGURE 7.3.1.2-4 TIMELINE #4 - LAUNCH SITE OPERATIONS

7.3.1.2 (Continued)

fueling will close down refurbishment operations, ordnance operations will impose RF silence on other operations, etc.,

2. End item testing: This will be completed prior to delivery to KSC.

7.3.2 Materials (Expendibles Consumption - AMLLV)

Calculations are based on experience gained on the Saturn program at Kennedy Space Center and at Mississippi Test Facility. This usage is costed elsewhere in the AMLLV and MLLV cost studies (Paragraphs 4.2.8.2 and 4.3.2.2).

a. This estimate is based on a cycle which includes:

1 - Core Stage (C/S) Static Firing

1 - Injection Stage (I/S) Static Firing

1 - *CDDT

1 - Countdown and Launch

b. LOX usage is as follows:

C/S Static Firing:	9,524,000 lb. in C/S LOX tank plus 3,178,000 lb. of losses
I/S Static Firing:	1,203,000 lb. in I/S LOX tank plus 401,000 lb. of losses
*CDDT	7,144,000 lb. of losses
Countdown:	10,727,000 lb. in Stage LOX tanks plus 3,572,000 lb. of losses
Total LOX/Cycle:	35,742,000 lb.

These quantities are based on AS-502,where approximately one pound of LOX is lost for each three pounds of LOX flight mass, and CDDT losses are approximately double the countdown losses.

*Count Down Demonstration Test

7.3.2 (Continued)

c. LH_2 usage is as follows:

C/S Static Firing:	1,586,000 lb. in C/S LH_2 Tank plus 539,000 lb. of losses
I/S Static Firing:	201,000 lb. in I/S LH_2 Tank plus 68,000 lb. of losses
CDDT:	1,429,600 lb. of losses
Countdown:	1,787,000 lb. in stage LH_2 tanks plus 607,600 lb. of losses
Total LH_2/Cycle	6,218,200 lb.

These quantities are based on AS-502 where approximately one pound of LH_2 is lost for each three pounds of LH_2 flight mass, and CDDT losses are approximately double the countdown losses.

d. The GHe usage is based on AS-502 where usage data indicates that the S-II and S-IVB stages used about 5 SCF of Helium per lb. of LH_2 for a total of approximately 1,100,000 SCF and an additional 7,000,000 SCF were used but not charged to a specific stage or GSE system.

For CDDT and countdown, usage is estimated to be 20,000,000 SCF of GHe (AS-502 used a total of 8,141,100 SCF). A reasonable estimate of total GHe usage for C/S and I/S Static Firing would be an additional 20,000,000 SCF for a total usage of 40,000,000 SCF for one complete cycle.

e. Gaseous Nitrogen usage based on AS-502 (332,000 gal. of LN_2 consumed) is estimated to be approximately 800,000 gal. of LN_2 for CDDT and countdown, to allow for increased LOX tankage pressurization requirements. C/S and I/S Static Firing GN_2 requirements are estimated at an additional 800,000 gal. of LN_2 for a total cycle usage of 1,600,000 gal. of LN_2.

f. Gaseous Hydrogen usage based on AS-502 (557,334 SCF) is scaled up from Saturn V to AMLLV to give CDDT/Countdown usage of 4,900,000 SCF. C/S and I/S Static Firing usage is estimated to be an additional 4,900,000 SCF for a total cycle requirement of 9,800,000 SCF of GH_2.

g. The water usage on AS-502 was 425,000 gal. during CDDT and Countdown. The flame deflector received water at 12,500 gpm and the launcher deck flush used a total of 25,000 gpm. This Saturn V data is included for information only.

7.3.2 (Continued)

since it does not correlate to the AMLLV launch conditions nor to the sustained cooling requirements inherent in a static firing.

h. No data is available for electrical power consumption usage on LC-39.

TABLE 7.3.2.0-I AMLLV/MLLV LAUNCH EXPENDABLE CONSUMPTION COSTS

ITEM	AMLLV	MLLV
Expendables:		
LOX	$ 447,000	$ 224,000
LH_2	3,159,000	1,579,500
GH_2	2,496,000	1,248,000
LN_2	346,000	173,000
GHe	92,000	46,000
Utilities	*	*
Total Cost Each Launch	$6,540,000	$3,270,500

*Included in Facility Maintenance Costs

7.3.3 Launch Vehicle Ground Support Equipment (LVGSE) and Tooling

Table 7.3.3.0-I outlines the flow of operations and identifies the facilities, tooling, and ground support equipment required. The following Table 7.3.3.0-I is a list of launch vehicle ground equipment and tooling, and briefly discusses each of the LVGSE and tooling items.

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 1 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 1.01 TITLE RECEIVE C/S AT LAUNCH COMPLEX	
1.01.01 - Attach unloading hoist to C/S	Gantry
1.01.02 - Transfer C/S to C/O and assembly silo	Gantry
1.01.03 - Unload C/S into silo	Gantry
1.01.04 - Transport C/S components to receiving inspection area	
1.01.05 - Perform C/S components receiving inspection (Heat Shields) (Skirts) (Access Panels) (Spares)	
1.02 POSITION AND CONFIGURE C/S FOR INSPECTION	
1.02.01 - Position C/S in C/O and assembly silo	(a) Gantry (b) Assembly and C/O fixture (c) Lifting sling
1.02.02 - Install external access fixtures	Work platforms providing 360^{o} access over the length of the C/S, and the engine area. (Part of assembly and C/O fixture)
1.02.03 - Remove protective covers and holding fixtures	None

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 2 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 1.02 (Continued) TITLE POSITION AND CONFIGURE C/S FOR INSPECTION	
1.02.04 - Install internal access fixtures	Stage; tanks, equipment section and engine section access platforms
1.03 CONDUCT C/S INSPECTION	
1.03.01 - Conduct internal and external stage inspection for in-transit damage	Hand tools and light fixtures
1.03.02 - Install C/S accessories (Heat shields, skirts, etc.)	Portable lifting devices
1.03.03 - Prepare electrical system for system test	No additonal equipment and facilities
1.03.04 - Prepare environmental system for system test	No additional equipment and facilities
1.03.05 - Prepare propulsion system for system test	No additional equipment and facilities
1.04 INSTALL STATIC TEST COMPONENTS	
1.04.01 - Install instrumentation electronics	No additional equipment and facilities
1.04.02 - Install RF system antenna hats	(a) Antenna hats (b) RF transmission system

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 1.05	TITLE PREPARE AND TRANSPORT C/S TO PAD SILO
1.05.01 - Remove internal access equipment and install access doors and holding fixtures	
1.05.02 - Attach hoisting device to C/S	Hoisting device, and launch pad gantry
1.05.03 - Transfer C/S to launch silo	Launch pad, gantry
1.05.04 - Lower and secure C/S in firing position	
1.05.05 - Remove handling equipment from C/S	
1.06	RECEIVE L/V STAGE AND FLIGHT COMPONENTS
No further breakdown required	Receiving facility only
1.07	INSPECT L/V STATIC AND FLIGHT COMPONENTS
1.07.01 - Review DD-250 package	
1.07.02 - Perform receiving inspection procedure	
1.07.03 - Accept hardware	
1.07.04 - Provide temporary storage	
1.07.05 - Provide controlled environment as required	

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 4 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 1.07 (Continued)	TITLE INSPECT L/V STATIC AND FLIGHT COMPONENTS
1.07.06 - Notify operations of equipment on dock	
1.08	TRANSFER STATIC L/V COMPONENTS TO STAGE REFURBISHMENT AREA
1.08.01 - Receive transfer request	
1.08.02 - Load components on transporter	Transporter
1.08.03 - Transport components to launch pad	Launch pad
1.08.04 - Transfer components to refurbishment area temporary storage facility	
1.09	TRANSFER FLIGHT COMPONENT TO STAGE REFURBISHMENT AREA
Same as 1.08	
1.10	RECEIVE I/S AT LAUNCH COMPLEX
1.10.01 - Position launch pad gantry over I/S barge slip	Launch pad gantry
1.10.02 - Attach I/S hoisting device	(a) Launch pad gantry (b) I/S hoisting device

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE <u>1.10 (Continued)</u> TITLE	<u>RECEIVE I/S AT LAUNCH COMPLEX</u>
1.10.03 - Transfer I/S to assembly and refurbishment silo	No additional equipment necessary
<u>1.11</u>	<u>POSITION AND CONFIGURE I/S FOR INSPECTION</u>
1.11.01 - Position I/S in C/O and assembly bay	(a) Overhead crane (b) Assembly and C/O fixture (c) Lifting sling
1.11.02 - Install external access fixtures	Work platforms providing 360° access over entire length of the I/S and engine area. (Part of assembly and C/O fixture)
1.11.03 - Remove protective covers and holding fixtures	None
<u>1.12</u>	<u>CONDUCT I/S INSPECTION</u>
1.12.01 - Conduct external inspection for intransit damage	Hand tools, and light fixtures
1.12.02 - Install I/S accessories (heat shield, skirts, etc.)	Portable lifting devices
1.12.03 - Prepare electrical system for system test	
1.12.04 - Prepare environmental system for system test	

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 6 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 1.12 (Continued)	TITLE CONDUCT I/S INSPECTION
1.12.05 - Prepare propulsion system for system test	
1.13	INSTALL STATIC TEST COMPONENTS
1.13.01 - Install instrumentation electronics	
1.13.02 - Install R.F. system antenna hats	(a) Antenna hats (b) R.F. transmission system
1.14	PREPARE AND TRANSFER TO PAD SILO
1.14.01 - Position launch pad gantry	Launch pad gantry
1.14.02 - Attach hoisting device to I/S	(a) Launch pad gantry (b) Hoisting device
1.14.03 - Hoist I/S from C/O and assembly bay	No additional equipment necessary
1.14.04 - Transfer I/S to launch silo	No additional equipment necessary

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 7 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 1.23 TITLE RECEIVE SRM's AT LAUNCH COMPLEX	
1.23.01 - Provide berth for SRM barge	
1.23.02 - Provide dockside facilities	Electric power, AC
1.23.03 - Change over from barge power to dockside power	
1.23.04 - Shutdown barge power system	
1.24 INSPECT SRM's	
1.24.01 - Review DD-250 package	
1.24.02 - Review barge log	
1.24.03 - Review on board instrumentation recordings	
1.24.04 - Enter SRM protective housing	
1.24.05 - Conduct visual inspection against DD-250 package	
1.24.06 - Inspect SRM core	Borescope
1.24.07 - Accept SRM	
1.24.08 - Notify operations of SRM on dock	

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 8 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 1.25 TITLE STORE SRM's AS REQUIRED	
1.25.01 - Provide berth for SRM barge	
1.25.02 - Provide dockside facilities	Electric power, AC
1.26 PREPARE AND TRANSFER SRM's TO LAUNCH PAD	
1.26.01 - Activate barge power supply	
1.26.02 - Change over from facility power to barge power	
1.26.03 - Disconnect facility power lines to barge	
1.26.04 - Cast off lines	
1.26.05 - Barge SRM to pad barge slip	
1.26.06 - Secure barge	
1.27 PREPARE LAUNCH SILO TO RECEIVE C/S	
1.27.01 - Calibrate Launch Silo	Static firing load calibration fixture
1.27.02 - Checkout core stage support and holddown structure	
1.27.03 - Checkout C/S service arms	

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 9 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 2.01	TITLE TEST AND CHECKOUT C/S STAGE
2.01.01 - Initiate communications between elements of launch complex	Operational intercom system Operational paging system
2.01.02 - Test subsystem	Central instrumentation facility computer complex Test and checkout computer Launch Vehicle control and display
2.01.03 - Checkout and calibrate subsystems	Test and checkout computer Launch vehicle control and display
2.01.04 - Acquire and record test, C/O and calibration data	Launch vehicle data recording system
2.02	CONDUCT FINAL SERVICING AND CLOSEOUT
2.02.01 - Service engines	C/S engine servicing equipment
2.02.02 - Conduct final systems checkout	C/S pneumatic system
2.02.03 - Remove access equipment	
2.02.04 - Replace access doors	

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 10 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 2.03 TITLE PERFORM PROPELLANT LOADING OF C/S	
2.03.01 - Connect fuel lines to stage	
2.03.02 - Purge fuel lines	GN_2 Purge system
2.03.03 - Chilldown propellant handling systems	GN_2 GH_e C/S pneumatic system
2.03.04 - Monitor for hazardous conditions	Hazardous gas detection system
2.03.05 - Monitor fueling operation	Launch vehicle monitoring system
2.03.06 - Fill LOX tanks	LOX facility Propellant tanking computer
2.03.07 - Fill LH_2 tanks	LH_2 facility Propellant tanking computer LH_2 heat exchanger
2.03.08 - Top up tanks	Propellant tanking computer
2.04 PERFORM STATIC FIRING OF C/S	
2.04.01 - Start up cameras	Operational Television System Photo Optical System Wideband Transmission System

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 11 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 2.04 (Continued) TITLE PERFORM STATIC FIRING OF C/S	
2.04.02 - Terminate fuel topping	
2.04.03 - Initiate static firing	Terminal countdown sequencer Launch vehicle control and display
2.04.04 - Monitor static firing performance	Static firing data acquisition system
2.04.05- Monitor static firing environment	Static firing data acquisition system Acoustics Measuring system Vibration Measuring system
2.04.06 - Cool silo	Water system
2.05 CONDUCT SHUTDOWN OPERATIONS	
2.05.01 - Conduct stage shutdown	Launch vehicle control and display
2.05.02 - Purge lines	
2.05.03 - Safe stage	
2.05.04 - Shutdown GSE systems	

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 12 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 2.06	TITLE PREPARE FOR TRANSFER TO REFURBISHMENT FACILITY
2.06.01 - Remove C/S from static fire holddown structure	No additional equipment
2.06.02 - Attach hoisting device	C/S hoisting device
2.07	TRANSPORT C/S TO REFURBISHMENT FACILITY
2.07.01 - Reposition launch pad gantry	Launch pad gantry
2.07.02 - Attach hoisting device and lift C/S from launch silo	Launch pad gantry
2.07.03 - Transfer C/S to refurbishment silo	No additional equipment
2.08	REFURBISH PAD FACILITY
2.08.01 - Inspect pad and identify damage	No refurbishment GSE identified
2.08.02 - Repair/replace damaged equipment as required	
2.08.03 - Conduct tests/checkout as required to verify adequacy of refurbishment repairs	

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 13 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 2.09	TITLE PREPARE PAD TO RECEIVE I/S
Same as for 1.27	
2.10	RECEIVE AND ERECT I/S IN LAUNCH SILO
2.10.01 - Receive I/S from c/o bay and transfer to firing position in launch silo	Launch pad gantry
2.10.02 - Lower and secure I/S in firing position	Launch pad gantry I/S transfer fixture SRM stage aft support and alignment fixtures (modified to support I/S for static firing)
2.10.03 - Mate counterweight to I/S	Gantry Core stage support and holddown structure
2.10.04 - Remove handling equipment from I/S	No additional equipment
2.10.05 - Connect GSE to I/S stage	Service arms, silo, I/S

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 14 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 2.11 TITLE TEST AND CHECKOUT I/S STAGE	
Same as 2.01	
2.12 CONDUCT FINAL SERVICING AND CLOSEOUT	
2.12.01 - Service engines	I/S engine servicing equipment
2.12.02 - Conduct fuel systems checkout	I/S pneumatic system
2.12.03 - Remove access equipment	
2.12.04 - Replace access doors	
2.13 PERFORM PROPELLANT LOADING OF I/S	
Same as 2.03	
2.14 PERFORM STATION FIRING OF I/S	
Same as 2.04	
2.15 CONDUCT SHUTDOWN OPERATIONS	
Same as 2.05	

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 15 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 2.16	TITLE PREPARE FOR TRANSFER TO REFURBISHMENT FACILITY
2.16.01 - Disconnect I/S service arms	
2.16.02 - Remove counterweight	Gantry
2.16.03 - Remove I/S from silo	I/S transfer fixture Gantry
2.17	TRANSFER I/S TO REFURBISHMENT FACILITY
No further breakdown required	I/S is transferred by gantry
2.18	REFURBISH PAD FACILITY
Same as for 2.08	

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 16 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 3.01 TITLE RECEIVE C/S IN REFURBISHMENT AREA - POSITION & CONFIGURE FOR POST FIRING INSPECTION	
3.01.01 - Install C/S on assembly and C/O fixture	Assemble and C/O fixture
3.01.02 - Remove handling device	No additional equipment
3.02 INSPECT AND DISASSEMBLE C/S	
3.02.01 - Remove engines	Mobile engine handling structure
3.02.02 - Move engines to inspection area and mount in inspection fixture	(a) Tractor (b) Portable Crane (c) Inspection Fixture
3.02.03 - Inspect engines	
3.02.04 - Inspect C/S	
3.03 REFURBISH C/S	
3.03.01 - Replace non-reusable components in C/S	
3.03.02 - Replace worn, damaged, or non-reusable parts in engines, and clean engines	Engine inspection fixture
3.03.03 - Clean and dry tanks and seal	Environmental Control System (ECS)
3.03.04 - Install engines	Mobile engine handling structure

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 3.04 TITLE INSTALL C/S FLIGHT COMPONENTS	
3.04.01 - Install G&C components	
3.04-02 - Install ordnance items	
3.05 CONDUCT C/S SYSTEMS TEST	
3.05.01 - Connect pneumatics supply	Pneumatics system
3.05.02 - Connect ECS	ECS
3.05.03 - Functional test G&C components	Test set
3.05.04 - Functional test fuel system components	Test set
3.05.05 - Leak check tanks and engines	Pressure test instrumentation
3.06 PREPARE AND TRANSFER C/S TO LAUNCH SILO	
3.06.01 - Attach hoisting device	Hoisting device
3.06.02 - Position launch pad gantry	Launch pad gantry
3.06.03 - Hoist C/S from inspection fixtures and remove from inspection area	No additional equipment
3.06.04 - Transfer C/S to launch silo	No additional equipment

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 18 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 3.07 TITLE RECEIVE I/S IN REFURBISHMENT AREA - POSITION & CONFIGURE FOR POST FIRING INSPECTION	
Same as for 3.01	
3.08 INSPECT AND DISASSEMBLE I/S	
3.08.01 - Remove engines	Mobile engine handling structure
3.08.02 - Move engines to inspection area and mount in inspection fixture	(a) Tractor (b) Portable Crane (c) Inspection Fixture
3.08.03 - Inspect engines	
3.08.04 - Inspect I/S	
3.09 REFURBISH I/S	
3.09.01 - Replace non-reusable components in I/S	
3.09.02 - Replace worn, damaged, or non-reusable parts in engines, and clean engines	Engine inspection fixture
3.09.03 - Clean and dry tanks and seal	Environmental Control System (ECS)
3.09.04 - Install engines	Mobile engine handling structure

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 19 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 3.10 TITLE INSTALL I/S FLIGHT COMPONENTS	
3.10.01 - Install G&C components	
3.10.02 - Install ordnance items	
3.11 CONDUCT I/S SYSTEMS TESTS	
3.11.01 - Connect pneumatics supply	Pneumatics systems
3.11.02 - Connect ECS	ECS
3.11.03 - Functional test G&C components	Test set
3.11.04 - Functional test fuel system components	Test set
3.11.05 - Leak check tanks and engines	Pressure test instrumentation
3.12 PREPARE AND TRANSFER I/S TO LAUNCH SILO	
3.12.01 - Attach hoisting device	Hoisting device
3.12.02 - Position launch pad gantry	Launch pad gantry
3.12.03 - Hoist I/S from inspection fixtures and remove from inspection area	No additional equipment
3.12.04 - Transfer I/S to launch silo	No additional equipment

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 20 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 4.01 TITLE PREPARE PAD TO RECEIVE C/S AND SRM's	
4.01.01 - Perform mechanical GSE systems checkout	Ground Equipment Test Sets (GETS)
4.01.02 - Perform electrical GSE system checkouts	Ground Equipment Test Sets (GETS)
4.02 RECEIVE SRM's	
4.02.01 - Position launch pad gantry	Launch pad gantry
4.02.02 - Attach SRM unloading hoist frame to gantry crosshead	Hoisting slings
4.02.03 - Transfer SRM to the stage rotating fixture	Rotating slip
4.02.04 - Rotate SRM to upright position	No additional equipment
4.03 POSITION SRM's IN SILO	
4.03.01 - Trnasfer SRM's to launch silo position	Launch pad gantry
4.03.02 - Lower SRM's in launch silo	No additional equipment
4.03.03 - Position and fix SRM's on SRM aft support	No additional equipment
4.04 POSITION C/S IN SILO	
4.04.01 - Align and lower C/S into silo position	Launch pad gantry

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 21 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 4.05 TITLE MATE SRM's TO C/S	
4.05.01 - Align and mate SRM's to C/S	Launch pad gantry
4.05.02 - Disconnect support arms from C/S and rotate out of way	
4.05.03 - Remove launch pad gantry	
4.06 ERECT I/S ON C/S	
4.06.01 - Emplace I/S on C/S	Pad gantry (Part of umbilical tower)
4.06.02 - Install access platform	Pad gantry
4.06.03 - Make structural and system connections	Pad gantry
4.07 MATE AND C/O L/V STAGES	
4.07.01 - Mate L/V umbilical connections	
4.07.02 - Perform limited L/V systems C/O	
4.07.03 - Inspect L/V - Payload interface and prepare for mating	

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 22 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 4.08 TITLE RECEIVE PAYLOAD	
4.08.01 - Offload payload	(a) Payload handling equipment (hoist slings) (b) Pad gantry
4.09 ERECT PAYLOAD ON L/V	
4.09.01 - Emplace payload on L/V	Pad gantry
4.09.02 - Perform alignment operations and make mechanical connections	Alignment set and facilities
4.10 MATE AND CHECKOUT STACKED VEHICLE (C/O S/V)	
4.10.01 - Install access platforms	(Part of umbilical tower)
4.10.02 - Mate systems connections - Payload to L/V	
4.10.03 - Mate umbilical connections - umbilical tower to payload	Umbilical tower
4.10.04 - Perform functional C/O of in-flight systems	
4.10.05 - Perform functional C/O of Launch Support Equipment (LSE) systems	
4.10.06 - Perform functional C/O of communications systems	

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 23 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 4.10 (Continued)	TITLE MATE AND C/O S/V
4.10.07 - Perform functional C/O of safety and abort systems	
4.11	PREPARE PAD SYSTEMS FOR STACKED VEHICLE (S/V) LAUNCH
4.11.01 - Position service structure at launch silo	Service structure
4.12	TEST AND CHECKOUT S/V
4.12.01 - Initiate communications between elements of launch complex	Operational Intercom System Operational Paging System
4.12.02 - Test subsystems	Central Instrumentation Facility Computer Complex Test and Checkout Computer Launch Vehicle Control and Display
4.12.03 - Checkout and calibrate subsystems	Test and Checkout Computer Launch Vehicle Control and Display
4.12.04 - Acquire and record test, C/O and calibration data	Launch Vehicle Data Recording System
4.12.05 - Install pyrotechnics	

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 24 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 4.13 TITLE INSTALL FLIGHT COMPONENTS AND CLOSEOUT	
4.13.01 - Service stage engines	C/S Engine Servicing Equipment I/S Engine Servicing Equipment
4.13.02 - Install flight batteries	
4.13.03 - Perform final G&N checkout	
4.13.04 - Conduct final systems checkout	C/S Pneumatic System I/S Pneumatic System
4.13.05 - Remove access equipment	
4.13.06 - Install thermal shielding	
4.13.07 - Deactivate service structure	
4.13.08 - Remove service structure	
4.13.09 - Connect and closeout safing and arming	
4.14 PERFORM PROPELLANT LOADING	
4.14.01 - Connect fuel lines to stage	
4.14.02 - Purge fuel lines	Purge System GN_2

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 25 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 4.14 (Continued)	TITLE PERFORM PROPELLANT LOADING
4.14.03 - Chilldown propellant handling systems	GN_2 GHe C/S Pneumatic System I/S Pneumatic System
4.14.04 - Monitor for hazardous conditions	Hazardous Gas Detection System
4.14.05 - Monitor fueling operation	Launch Vehicle Monitoring System
4.14.06 - Fill LOX tanks	LOX Facility Propellant Tanking Computer
4.14.07 - Fill LH_2 tanks	LH_2 Facility Propellant Tanking Computer LH_2 Heat Exchanger
4.14.08 - Top up tanks	Propellant Tanking Computer
4.15	PERFORM TERMINAL COUNTDOWN
4.15.01 - Monitor abort parameters	Abort Advisory System
4.15.02 - Start Up Cameras	Operational Television System Photo Optical System Widebank Transmission System
4.15.03 - Terminate Fuel Topping	

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 26 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 4.15 (Continued) TITLE PERFORM TERMINAL COUNTDOWN	
4.15.04 - Transmit data to other centers	Launch Data System - Huntsville Launch Data System - Houston
4.15.05 - Monitor Launch Environment	
4.16 LAUNCH S/V	
4.16.01 - Ignite SRM's	
4.16.02 - Ignite core stage	
4.16.03 - Retract service arms	
4.16.04 - Cool silo and launch umbilical tower	Water System
4.16.05 - Monitor launch environment	Acoustics Measuring System Vibration Measuring System
4.17 CONDUCT CLOSE DOWN OPERATION	
Same as for 2.05	

TABLE 7.3.3.0-I SUB-OPERATION - FACILITY AND EQUIPMENT REQUIREMENTS (SHEET 27 OF 27)

SUB-OPERATION	FACILITY & EQUIPMENT REQUIREMENTS
CODE 5.01 TITLE CONDUCT POST LAUNCH PAD INSPECTION	
No further breakdown required	No GSE identified
5.02 REFURBISH PAD FACILITY	
No further breakdown required	No GSE identified

7.3.3 (Continued)

a. Description of Launch Vehicle GSE (LVGSE) and Tooling

Only one of each system required, except as otherwise noted.

1. *C/S Engine Servicing

This system is expected to be similar to the J-2 Engine Servicing currently used at LC-39, since both the J-2 and the AMLLV engines will be oxygen-hydrogen engines.

2. ** I/S Engine Servicing

Same as rationale, C/S Engine Servicing.

3. C/S Pneumatic System

This system provides regulated helium, chilled helium, nitrogen and gaseous hydrogen to the C/S stage. The helium and nitrogen will be provided to this system from the facility gaseous helium and nitrogen systems at 6000 psi. The helium will be chilled in a heat exchanger (part of this system) using cold vaporized hydrogen from the LH_2 Heat Exchanger (Item 13). The pneumatic system provides stage requirements for purging, checkout, pressurization, chilldown and inerting. This system is similar to the S-II Pneumatic System at LC-39.

4. I/S Pneumatic System

This system is similar to the C/S Pneumatic System above.

5. Launch Vehicle DC Power

This system converts AC power from the facility High Voltage AC Power Distribution System to DC power to meet all launch vehicle power requirements. Power of the proper voltage level and quality will be provided at the silo, the service structure, the LUT and both refurbishment areas. This system includes a backup battery capability capable of conducting system shutdown and securing in the event of power failure. This system is equivalent to the ESE Primary Power System at LC-39 that supplied power requirements of the IU, S-IVB, S-II and S-IC stages.

* Core (Main) Stage.

** Injection Stage

7.3.3 (Continued)

6. Test and Checkout Computer

This computer is a GSE equivalent to the master T&C/O Computer that is located in the payload. This computer can "talk" to the stage computers, conduct any and all functions the flight computer can do, and in addition can accept commands from the ground equipment and provide data and status.

7. Terminal Countdown Sequencer

The sequencer performs a similar function to the Terminal Countdown Sequencer at LC-39. This equipment on AMLLV also has a capability to perform a static firing countdown sequence for both the C/S and I/S static firings.

8. Launch Vehicle Environmental Control System (ECS)

This system provides a control environment for the C/S and I/S. Both stages include a flight computer and other electronics which are used for test and checkout as well as operational flight control. During these tests and checkout functions, the Environmental Control System will provide temperature and humidity controlled air. Prior to the start of cryogenics loading, the Environmental Control System will change over to provide controlled nitrogen to the stages. This system will be similar to the ECS at LC-39.

9. Launch Vehicle Control and Display

This system provides the means of manually controlling the launch vehicle from the T/LCC.* This system includes consoles for the stages, an operational computer and sufficient status displays to enable the operators to control stage operations. This system includes consoles for the I/S and C/S, stage power and stage pneumatics.

10. Launch Vehicle Command and Control Computer

This system links the Launch Vehicle Control and Display System consoles to the stages and stage peculiar GSE (LVGSE). This system calls up and performs routines in response to commands inserted at the consoles. Approximately 5,000 discretes and analog signals are processed by this system. These signals are used to verify operations, ensure in-tolerance performance, and maintain proper sequence of operations. Selected data is transmitted to the consoles for display to provide status to the operators.

*Test/Launch Control Center

7.3.3 (Continued)

11. Launch Vehicle Monitoring System

This system monitors the stages and stage peculiar hardware. The points monitored by this system are those not used by the Launch Vehicle Command and Control Computer in performing its functions. The data handled by this system is processed and stored during normal operation. A computer which is part of this system compares the data to redline values and event sequences. Whenever a redline is exceeded or an out-of-sequence operation is detected, the condition will be displayed at the T/LCC.

12. GH_2 Supply

This system provides GH_2 to the C/S and I/S Pneumatic Systems for stage pressurization. This system converts liquid hydrogen to gaseous hydrogen at the pressures and flow rates required by the stages.

13. C/S Transfer Fixture

This fixture is used to handle the main stage in a vertical position using the gantry crane. Loads related to raising and lowering the stage and to lateral travel are transmitted through this fixture to the stage hard points.

14. I/S Transfer Fixture

This fixture is similar to the C/S Transfer Fixture, Item 13 above.

15. Borescope

This device is used to examine the core of the assembled SRM for visible damage.

16. C/S Antenna Hat (2 Required)

(Self Explanatory)

17. Mobile Engine Handling Fixture

This fixture is used to remove, install, and transport both I/S and C/S engines.

7.3.3 (Continued)

18. Engine Inspection Fixture

This fixture is used to hold and position I/S and C/S engines for inspection prior to use and after static firing.

19. C/S Pneumatic System - Refurbishment Area

This system provides regulation and control of GN_2 and GHe in the refurbishment area. These gases are used for leak testing, pressure checks, purging, and inerting.

20. C/S Guidance and Control (G&C) Functional Test Set

This equipment is capable of providing input signals to the G&C, and checking the G&C responses against the specified responses to determine that the G&C is operating within tolerances.

21. C/S Fuel System Functional Test Set

This equipment performs a functional test on the C/S fuel system to determine if the system is operating within allowable tolerances.

22. C/S Fuel Tank Leak Check Equipment

This equipment performs leak checks on the C/S fuel tanks by pressurizing the tanks and measuring the rate of pressure decay.

23. I/S Pneumatic System - Refurbishment Area

This system is similar to the C/S Pneumatic System - Refurbishment Area, Item 19.

24. I/S G&C Functional Test Set

This system is similar to the C/S G&C Functional Test Set, Item 20.

25. I/S Fuel System Functional Test Set

This system is similar to the C/S Fuel System Functional Test Set, Item 21.

7.3.3 (Continued)

26. I/S Fuel Tank Leak Check Equipment

This system is similar to the C/S Fuel Tank Leak Check Equipment, Item 22.

27. S/V Alignment Set

This system is used to align the launch vehicle during the stacking process and includes both azimuth alignment of each stage and vertical straightness of stacked vehicle. The azimuth alignment provisions are used to align the stages in the static firing configuration as well as in the launch vehicle configuration.

28. SRM Electronic Checkout Van

This system consists of van mounted electronic checkout equipment complete with a self-contained power supply.

29. SRM Hydraulic Power Servicing Unit

This unit contains hydraulic pumps, reservoir, and regulation equipment to service the hydraulic equipment on the SRM.

30. SRM Motor Leakage Pressurization Unit

This is capable of pressurizing and measuring pressurization rate-of-decay caused by motor leakage.

31. SRM Pneumatics Power Supply Cart

This cart provides SRM pneumatic power requirements for test and checkout.

32. SRM Aft Skirt Assembly Fixture

(Self Explanatory)

33. SRM Aft Skirt Handling Sling

(Self Explanatory)

7.3.3 (Continued)

34. SRM Aft Skirt Tool Kit

This kit contains the special tools used in the assembly and installation of the SRM Aft Skirt.

35. SRM Nozzle/TVC Alignment Kit

This kit is used to align the thrust vector control provisions and the engine nozzle.

36. SRM Exit Cone Handling Kit

(Self Explanatory)

37. SRM Exit Cone Tool Kit

This kit contains the special tools used in the installation of the Exit Cone.

38. SRM & Actuator Handling Slings

(Self Explanatory)

39. SRM Maintenance Stands

(Self Explanatory)

7.3.4 AMLLV/MLLV GSE Equipment

This section contains a facility equipment list under paragraph 7.3.4.1. Certain items of these facilities GSE equipments could be categorized variously as tooling, facilities, and/or ground support equipment. The method adopted was selected for the purpose of costing.

Paragraph 7.3.4.1 contains a GSE equipment description for each item on the equipment list in 7.3.4.1. This facilitated cost studies and design identification.

7.3.4.1 AMLLV/MLLV GSE Equipment List

FACILITY GSE	NO. OF SYSTEMS
1. Launch Umbilical Tower	1
2. Service Structure	1

7.3.4.1 (Continued)

FACILITY GSE	NO. OF SYSTEMS
3. Gantry, Track Mounted	1
4. SRM Rotating Fixture	1
5. Service Arms, Launch Umbilical Tower	3
6. SRM Stage AFT Support & Alignment Fixtures	12
7. SRM Unloading Hoist Frame	1
8. SRM Forward Attach & Alignment Boom Mechanism	4
9. Core Stage Support and Holddown Structure	4
10. Restraining Snubbers	4
11. Injection Stage Static Firing Support Fixture	1
12. Injection Stage Counterweight Module	1
13. Roll Ramp Actuator	16
14. C/S Refurbishment Work Platforms	4
15. I/S Refurbishment Work Platforms	3
16. LOX Facility (Barge Mounted)	1
17. LH_2 Facility (Barge Mounted)	1
18. High Voltage AC Power Distribution	1
19. Gaseous Nitrogen System	1
20. Gaseous Helium System	1
21. Propellant Tanking Computer	4
22. Water System	1
23. Wideband Transmission System	1

7.3.4.1 (Continued)

FACILITY GSE	NO. OF SYSTEMS
24. Operational TV System	1
25. Purging System	1
26. Abort Advisory	1
27. Operational Intercom System	1
28. Photo Optical System	1
29. Launch Data System - Houston (Similar to Apollo Launch Data System - ALDS)	1
30. Launch Data System - Huntsville (Similar to Launch Information Exchange Facility -- LIEF)	1
31. Operational Paging System	1
32. Facility Systems Control & Display (T/LCC)	1
33. Hazardous Gas Detection System	1
34. Acoustics Measuring System	1
35. Vibration Measuring System	1
36. Central Instrumentation Facility Computer Complex	1
37. Facility Command and Control Computer (Similar to Data Transmission System - DTS)	1
38. Instrumentation Data Display System (Similar to Data Display System)	1
39. Facility Monitoring System (Similar to Data Acquisition System - DAS and Digital Events Evaluator - DEE-3)	1
40. Central Instrumentation Telemetry System	1
41. Count Clock	1
42. Service Arms, Silo, C/S	2
43. Service Arms, Silo, I/S	4

7.3.4.1 (Continued)

FACILITY GSE	NO. OF SYSTEMS
44. Static Firing Load Calibration Fixture	1
45. Ground Equipment Test Set	1
46. Core Stage Counterweight Module	1
47. Injection Stage Positioning & Counterweight Module	1
48. Facility DC Power	1

7.3.4.2 AMLLV GSE Equipment List Description

Facility GSE

a. Launch Umbilical Tower (LUT)

The LUT is a stationery structure which supports three or more launch umbilical swing arms, each of which retract to provide clearance as required. Height above pad is approximately 300 feet. This structure is similar to the LC-39 LUT from the zero level on up.

b. Mobile Service Structure (MSS)

The service structure is rail mounted. Prior to launch, the service structure is to be stationed on the end of the launch pad opposite the barge slip. It is moved forward on the rails to service the stacked vehicle. The service structure is approximately 300 feet high, approximately 150 feet deep and 350 feet wide. The service structure is self-propelled. The structure is similar to the existing MSS on LC-39.

c. Gantry, Track (Rail) Mounted

The gantry must be capable of traversing the length of the launch pad, from barge slip across and over the refurbishment areas to the launch silo and beyond. Lifting is to be accomplished with synchronized Roll Ramp Actuators, permitting precision positioning of the stages during stage testing and vehicle assembly operation. Sufficient clear span is provided for the largest loads, and to clear the highest assembled vehicle configuration. The load travel, horizontally, is to be approximately 140 feet, and a minimum lift height of 390 feet to load girder. The gantry should be capable of traversing 1000 feet in one hour. The maximum gantry load is the 4,200,000 lb. SRM stage, plus the weight of the hoisting frame.

7.3.4.2 (Continued)

d. SRM Rotating Fixture

The SRM rotating fixture is a device to accept the SRM in a horizontal position and rotate it to vertical position so that it may be handled by the launch pad gantry, for insertion into the launch silo. The device must rotate an SRM weighing 4,200,000 lb., 120 feet in length, and 260 inches in diameter.

e. Service Arms, Launch Umbilical Tower

The function of the arms, supported by the associated equipment, is to provide support and disconnect capability for the umbilical service lines and electrical cables. Each arm is to be supported by two hinge assemblies, one on the arm top chord and one on the bottom chord. Each hinge assembly will contain a bearing assembly, hydraulic cylinder, lock unit, piping, and electrical wiring. The upper hinge will contain a slewing ring assembly, deceleration valve, and an arm position sensor. The lower hinge will have a safety gate insert attached to the hinge weldment. The speed of retraction of each arm will be controlled by the cam-operated deceleration valve which will provide the desired discharge flow rates from the hydraulic cylinders.

f. SRM Stage Aft Support & Alignment Fixtures (12 each AMLLV or 8 each MLLV)

SRM stage aft support is roller mounted so as to permit movement in or out of the silo wall to position the SRM stages. Each is designed to carry static loads up to 6,000,000 lbs. The design is such that upon lift-off at launch, the SRM supporting ring will rise in an arc until the support ring is pivoted into a recess in the silo wall. The support has alignment capabilities in that after the SRM's are lowered onto the SRM stage support and alignment fixtures by the overhead gantry, braces are attached to the upper end of each SRM stage and the alignment support is retracted so that the stage is adjacent to the silo wall. After the core stage has been lowered into the silo, the support and alignment fixtures permit the SRM's to be aligned and mated to the core stage.

g. SRM unloading Hoist Frame

The hoist lift frame will elevate the load to the level of the launch pad dock. It is to be powered by roll ramp actuators. The hoist frame spanning the unloading slip is to be removable from the four synchronized roll ramp "elevators" when the load reaches the deck of the launch pad. The gantry crane will continue with the second stage of the lift.

7.3.4.2 (Continued)

h. SRM Forward Attach and Alignment Boom Mechanism

The SRM forward attach and alignment boom is a stage-to-deck brace (hydraulic alignment boom) to be attached before the hoist is disconnected from the stage. They are to be used to position the forward (upper) end of the SRM to the core for attachment, and are to be removed after the SRM stage has been mated to the core.

i. Stage Support and Holddown Structure

This is a boom assembly, the purpose of which is to position the core stage while attaching the SRM stages prior to launch, and to serve as holddown arms.

j. Restraining Snubbers

Restraining snubber is a device to be mounted on the SRM stage aft supports to maintain core stage alignment during static firing.

k. Injection Stage Static Firing Support Fixture

The injection stage cannot be static fired in its normal launch position. Special fixtures and jigs must be designed to support the injection stage in the static firing position. They will consist of a ring or belt type harness attachment that will provide a static firing mode similar to that of the core stage.

l. Injection Stage Counterweight Module (AMLLV)

This module is 71.7 feet in diameter, 118.0 feet high, and weighs:

$$W_{cw} = W_{IS} \times \text{T/W Ratio} \times 1.5 \text{ Safety Factor}$$

$$= 1{,}614{,}000 \text{ lb} \times 1.5 \text{ est.} \times 1.5$$

$$= 3{,}631{,}500 \text{ lb (AMLLV}$$

$$W_{cw} = 805{,}500 \text{ lb} \times 1.5 \text{ est.} \times 1.5 = 1{,}812{,} 375 \text{ lb (MLLV)}$$

This module will interface with the I/S and the Core Stage Support and Holddown Structure.

m. Roll Ramp Actuator

The roll ramp actuator hoist is made up of eight (8) 1,500,000 pound load actuators (manufactured by Philadelphia Gear Corp.) that operate on

threaded lift stems. Four pairs of these will simultaneously lift a hoist frame with an SRM attached to the frame. The length of the screw (threaded lift stem) for each will be 400 feet. These will be built in short lengths and welded on site to give the overall length. The purpose of this device is to lift stages from the barge slip level to the deck level of the launch pad. The gantry is equipped with an additional eight roll ramp actuators (four pairs).

n. C/S Refurbishment Work Platforms

C/S refurbishment work platforms will be stationed in the surrounding walls of the refurbishment silo and will be lowered as required to work on specific stations of the stage. The required number of platforms will be dictated by the various configurations to be refurbished.

o. I/S Refurbishment Work Platforms

(See Item h above).

p. LOX Facility (Barge Mounted)

This system consists of LOX storage tanks mounted on a barge and a LOX pumping station located adjacent to the LOX barge dock. The AMLLV has a LOX capacity of about 2.47 times the Saturn V (10,717,460 lbs. of LOX for AMLLV, 4,331,843 lbs. for Saturn V). Since the LC-39 LOX system has a tank capable of holding 900,000 gallons (8,577,000 lbs.), the AMLLV tank or tanks should have a minimum capacity of approximately 2,000,000 gallons (20,000,000 lbs) to allow an adequate margin for boiloff and chilldown. The pump station will require approximately twice the fill and topping capacity as the LC-39 system has, or about 20,000 gpm fill and 2,000 gpm replenish. This system is roughly 2-1/2 times as big as the LC-39 system. (MLLV = 4,757,150 lbs. x 1.98 = 9,419,157 lbs.)

q. LH_2 Facility (Barge Mounted)

This system consists of LH_2 storage tanks mounted on a barge and an LH_2 tank pressurization system. The AMLLV has an LH_2 capacity of about 8.76 times the Saturn V (1,786,700 lb. for AMLLV, 203,895 lb. for Saturn V). Since the LC-39 LH_2 system has a tank capable of holding 850,000 gallons (502,350 lb.) the AMLLV tank or tanks should have a minimum capacity of about 7,500,000 gallons (4,400,000 lb.) to allow an adequate margin for boiloff and chilldown. Tanking of the AMLLV will be accomplished by maintaining a storage tank pressure of 60 psi for ullage. This system is roughly 9 times as big as the LC-39 system. (MLLV: LH_2 = 792,850 lbs. x 1.98 = 1,569,843 lbs.)

7.3.4.2 (Continued)

r. High Voltage AC Power Distribution

This system provides AC power to the entire AMLLV/MLLV Launch Complex and would be comparable to the system that supplies LC-39. The AMLLV/MLLV complex would receive 69/115 KV power from Florida Power & Light Co. at a major substation on the mainland. 13.8 KV would be distributed to switching stations located at the Test & Launch Control Center, the Launch Equipment Shop, the LOX Barge Dock, the LH_2 Barge Dock, the Launch Pad, the Stage Acceptance Testing and Checkout Area, the Central Instrumentation Facility, and the Mainland LOX and LH_2 facilities. Each of these switching stations would supply local substations at 4160/2400 VAC (about 30 substations are estimated). Each substation provides power to the user at levels of 480 VAC, 120/208 VAC, and 115 VAC as required. The using systems would convert this power to direct current as required.

s. Gaseous Nitrogen System

This system receives GN_2 at 7000 psig from an off-site source. The GN_2 is reduced to 6000 psig at a reducing station and stored in a battery at the pad. The replenish capacity will be 500 lb/min and the storage capacity will be approximately 50,000 lbs. GN_2 will be distributed at 6000 psig to the LUT, the Service Structure, the Silo, both refurbishment areas, and to the LOX and LH_2 facilities.

t. Gaseous Helium System

This system receives gaseous helium from tub bank rail cars at 2200 to 4000 psig. The helium is converted to 6000 psig and transferred to a storage battery at the pad. This system is estimated to be larger than the LC-39 HPGHe facility by a factor of 2. The helium is distributed at 6000 psig to the LUT, Service Structure, Silo, both refurbishment areas, and the LOX and LH_2 facilities.

u. Propellant Tanking Computer (PTC)

The propellant tanking computer is made up of an independent computer for each tank. The PTC for AMLLV has 4 computers compared to 6 for Saturn V. The individual AMLLV computers would be identical to the Saturn V computers. Each tanking computer system is composed of a display and control console, a manual computer, a manual ratiometer, an automatic computer, a discrete generator, an automatic ratiometer and a valve control assembly.

7.3.4.2 (Contiued)

v. Water

This system supplies all water requirements for the AMLLV complex. This includes potable water, industrial water, fire protection water, and deluge system water. The major difference between the AMLLV and the LC-39 water systems is the quantity of deluge water required for pad cooling/protection.

w. Wideband Transmission System

The wideband transmission system provides the cabling between locations on the AMLLV complex for the transmission of video and audio signals. This system is estimated to be equivalent to the LC-39 wideband transmission system except that the cable runs will be approximately twice the number of data link transmission repeaters in the runs.

x. Operational TV System (OTV)

This system can be considered to be identical to the LC-39 OTV system. The system is composed of 60 cameras, the equipment necessary to control, modulate, and mix signals at the Pad for transmission to the Launch/Test Control Center, and equipment at the T/LCC equipment will include a 60 x 100 switching unit capable of switching any camera output to any TV monitor (total of 100) with a manual patch board backup. Each camera will have a zoom, tilt, and pan capability and adequate protection to operate through the static test firing and launch environment.

y. Purging System

The purging system is a system for distributing low pressure (50 psig) GN_2 to electrical equipment located on the service structure, LUT, silo area, and fuel storage facilities. This includes pressure reduction equipment to reduce GN_2 from the Gaseous Nitrogen System down from 6000 psig to 50 psig.

z. Abort Advisory

This system monitors critical safety parameters. Whenever a catastrophic event is initiated, this system provides visibility to the Launch Director and the means for him to initiate payload abort sequences. For manned missions, the abort status is transmitted to the flight crew for action. The system is composed of abort advisory consoles and telescope observation stations. This system acquires abort information

7.3.4.2 (Continued)

from other GSE systems such as the operation TV system, the hazardous gas detection system, the central instrumentation facility telemetry and computer systems, and the launch vehicle control and display equipment. Specific inputs to the Abort Advisory System include hazardous gas, C/S and I/S tank pressure, engine thrust chamber pressure, engine position, and visual and TV observation.

aa. Operational Intercom System (OIS)

The Operational Intercom System is similar to the OIS at LC-39. This system provides voice communications for test and operations personnel between the facilities that makeup the AMLLV complex. Both hardware and RF links are used between locations. This system interfaces with the commercial telephone system and off-complex circuits such as range safety.

ab. Photo Optical System

The photo optical system provides photographic coverage of static firings and launch. This system would take both still and movie pictures from various locations in and around the pad. This system includes a console and equipment to remotely operate the photographic cameras. Cameras at two peripheral locations are mounted on mobile tracking devices, which are pointed using operational TV cameras that are boresighted to the mobile trackers. This system would include approximately 150 cameras.

ac. Launch Data System - Houston

This system is similar to the Apollo Launch Data System (ALDS) used at LC-39. It reduces payload data of various types including video to digital format and transmits this data to Houston, transmits up to two video pictures to Houston and receives digital data from Houston.

ad. Launch Data System - Huntsville

This system is similar to the Launch Information Exchange Facility (LIEF) system at LC-39. This system provides the data exchange function with Huntsville, similar to the ALDS data exchange with Houston described in item 29 above.

7.3.4.2 (Continued)

ae. Operational Paging System

The paging system is located throughout the complex to provide coverage of all operational areas. This system is similar to the Operational Paging system at LC-39.

af. Facility Systems Control and Display

This system provides the means of manually controlling the facility GSE systems from the T/LCC. This system includes consoles for the systems that operate in the vicinity of the launch silo during and after cryogenic fueling, an operational computer and sufficient system status displays to enable the system operators to control this system operations. This system includes four consoles for the stage tank Propellant Tanking Computers, and consoles for control of systems such as the Power Distribution System and the Water System. This system provides the man-machine interface with the Facility Command and Control Computer.

ag. Hazardous Gas Detection System

This system measures minute amounts of hazardous gases that may accumulate in critical areas of the Launch Vehicle and in the propellant storage and handling areas. The system includes vehicle monitoring manifolds, a hazardous gas analyzer, sensors such as hydrogen flame deflectors and thermal wire detectors, a hazardous gas display and alarm system, and a recording system. A console is provided in the LCC to display hazardous gas status and Detection System status. This system is similar to a combination of the LCC Measuring and Hazardous Gas Detection system and the Hazards Monitoring subsystem of the Facility Measuring and Hazards Monitoring system at LC-39.

ah. Acoustics Measuring System

This system senses and records acoustic levels in and around the pad area during stage static firing and vehicle launch. The system includes approximately 50 microphones located in the pad vicinity and associated tape recording equipment. This system includes six portable acoustic sensing and recording devices. Sound pressure levels and noise frequency spectrums can be determined, by analysis of the tapes, for each pickup location after a firing or launch. This system is similar to the Acoustics Measuring Subsystem of the Facility Measuring and Hazards Monitoring System at LC-39.

7.3.4.2 (Continued)

ai. Vibration Measuring System

This system measures static firing and launch vibration environment at approximately 350 points in and around the pad. All vibration data is recorded for future analysis and 25 of the points are displayed in real time at a console in the T/LCC during a launch or static firing. This system is similar to the Vibration Data Acquisition subsystem of the Facility Measuring and Hazards Monitoring System at LC-39.

aj. Central Instrumentation Facility Computer Complex

This system is primarily composed of a large computer with a large memory storage. This computer receives payload, launch vehicle and down-range data from the Central Instrumentation Facility Telemetry System, processes the data and stores it in the memory banks. Data is called up for static firing or launch status purposes by the Instrumentation Data Display System and displayed at the T/LCC on Eidophor projectors and conventional TV monitors. This system is also the source for Huntsville and Houston Launch Data and for real time quick look data during a firing or launch. The system includes all the associated necessary conversion equipment, video switching, accessing equipment, etc. This system is similar to the Data Translation Subsystem of the Data Display System at LC-39.

ak. Facility Command and Control Computer

This system links the Facility Systems Control and Display Consoles to the Facility GSE systems. This system calls up and executes stored routines in response to commands inserted at the consoles. Approximately 2000 discretes and analog signals from the facility systems are processed by this system. These signals are used to verify operations, assure in-tolerance system performance and maintain proper sequence of operations. Selected data is transmitted to the consoles for display to provide system status to the operators.

al. Instrumentation Data Display System

This system calls up and displays data from the Central Instrumentation Facility Computer Complex for static firing and launch status and for quick look purposes. The data is displayed in the T/LCC on Eidophor projectors and conventional TV monitors. This system is similar to the Data Presentation Subsystem of the Data Display System at LC-39.

7.3.4.2 (Continued)

am. Facility Monitoring System

This system monitors the facility GSE systems. The points monitored by this system are those that are not used by the Facility Command and Control Computer System in performing its functions. The data handled by this system is processed and stored during normal operation. A computer which is part of this system compares the data to red line values and event sequences. Whenever an allowable red line is exceeded or an out-of-sequence operation is detected, the condition will be displayed at the T/LCC. This system performs a function similar to the Digital Events Evaluator (DEE-3) at LC-39.

an. Central Instrumentation Facility Telemetry System

This system receives the telemetry data that is processed and stored in the Central Instrumentation Facility Computer Complex. This data is originated at the pad and at a down range source.

ao. Count Clock

This system provides all timing information for the launch complex. This timing is used to synchronize operations to provide a time base for relating data, and to relate AMLLV timing to that of other systems. This system also includes the countdown clock which provides the time base for the final static firing and countdown system and the count clock at LC-39.

ap. Service Arms, Silo, Main Stage (C/S)

The service arms are structural members extending from the silo walls to the skin of the core stage. The purpose of these arms is to provide structural support to fluid lines and electrical conductors from the time the core stage is installed in the silo until the final seconds before static firing or launch. At this point in time, the service arm retracts to a position that will not interfere with liftoff, and that will also offer protection to the service arms from the effects of either the static firing or launch environment. These service arms will be similar to those used on LC-39 to service the stages.

aq. Service Arms, Silo, Injection Stage (I/S)

Two service arms are similar to the C/S service arms, and two others are used only during I/S static firing. During a launch the latter two, which are not used, are protected in recesses within the silo walls.

7.3.4.2 (Continued)

ar. Static Firing Load Calibration Fixture

This fixture is a device used to place known static loads on the equipment used in and around the silo area to support a static test firing of either the C/S or I/S. The purpose of this fixture is to calibrate the various static firing instrumentation systems.

as. Ground Equipment Test Set (GETS)

This equipment is used to check out electrical/electronic portions of the GSE equipment at the drawer or cabinet level. The GETS will provide inputs to the piece of equipment being tested and evaluate the responses to determine if the equipment is performing properly.

at. Main Stage Counterweight Module

This module is mounted on the core stage during static firing to weight down the stage sufficiently to prevent achieving a lift-off.

au. Injection Stage Counterweight Module

I/S positioning and counterweight module serves the same function as the C/S module, and in addition provides the means to position the I/S for static firing.

ar. Facility DC Power

This system converts AC power from the High Voltage AC Power Distribution System to DC power to supply facility DC power requirements. This system is the equivalent of the Mobile Launcher Auxiliary Power and the LCC Auxiliary Power subsystems of the ESE Primary Power System at LC-39. This system includes backup battery capacity to provide for an orderly shutdown and safing in the event of a power failure.

7.3.5 Facilities

The launch complex will consist of a:

Launch Pad;

Test and Launch Control Facility;

Launch Equipment Shop;

7.3.5 (Continued)

SRM Receiving, Test and Storage Area;

Fuel Barge Docking Facility;

Other Facilities as Required: e.g., Camera and Observation Site,

Cross Country Piping Between Fuel Barge Docking Facility and Launch Pad.

7.3.5.1 Launch Facility Layout

A site was chosen at the northern limits of the Kennedy Space Center, as far removed as possible from centers of population, for the location of the AMLLV/MLLV launch complex for graphic representation. This location was ground ruled for the purpose of this study.

All stages will arrive at the launch complex by barge from the manufacturing facilities. All-systems test and checkout will have been accomplished at the manufacturing facilities. Normal receiving inspection will be accomplished at special barge docking facilities, with final systems check on the pad prior to firing.

Static firing of each stage will be performed on the launch pad. After sufficient static firing tests have been performed on early production models, reliability assurance will be established so that static firings prior to launch may no longer be necessary. Vehicle stacking and assembly will be on pad, in-place assembly. This will be described in detail in subsequent sections illustrating launch pad configuration.

The LH_2 and LOX barge docking facilities will be remotely located so as to be protected from launch hazards. Underground propellant lines will service the launch pad during fueling or de-fueling operations. Normal support facilities such as shops, power stations, transportation facilities, etc., will be located on the mainland. Normal logistics supply to the launch facility will be either by barge or by vehicle across the causeway. Previously shown Figure 7.2.0.0-1, illustrates the AMLLV/MLLV - General Launch Facility Concept.

7.3.5.2 Launch Pad

The launch pad as shown in Figure 7.3.5.2-1 is a massive structure of concrete and steel. It is honeycombed with service areas, refurbishment facilities, passage-ways and tunnels carrying power and communication lines, propellants, gasses and liquids. The entire complex is engineered to contain all facilities, handling, test and shop equipment required from receipt of stages and modules,

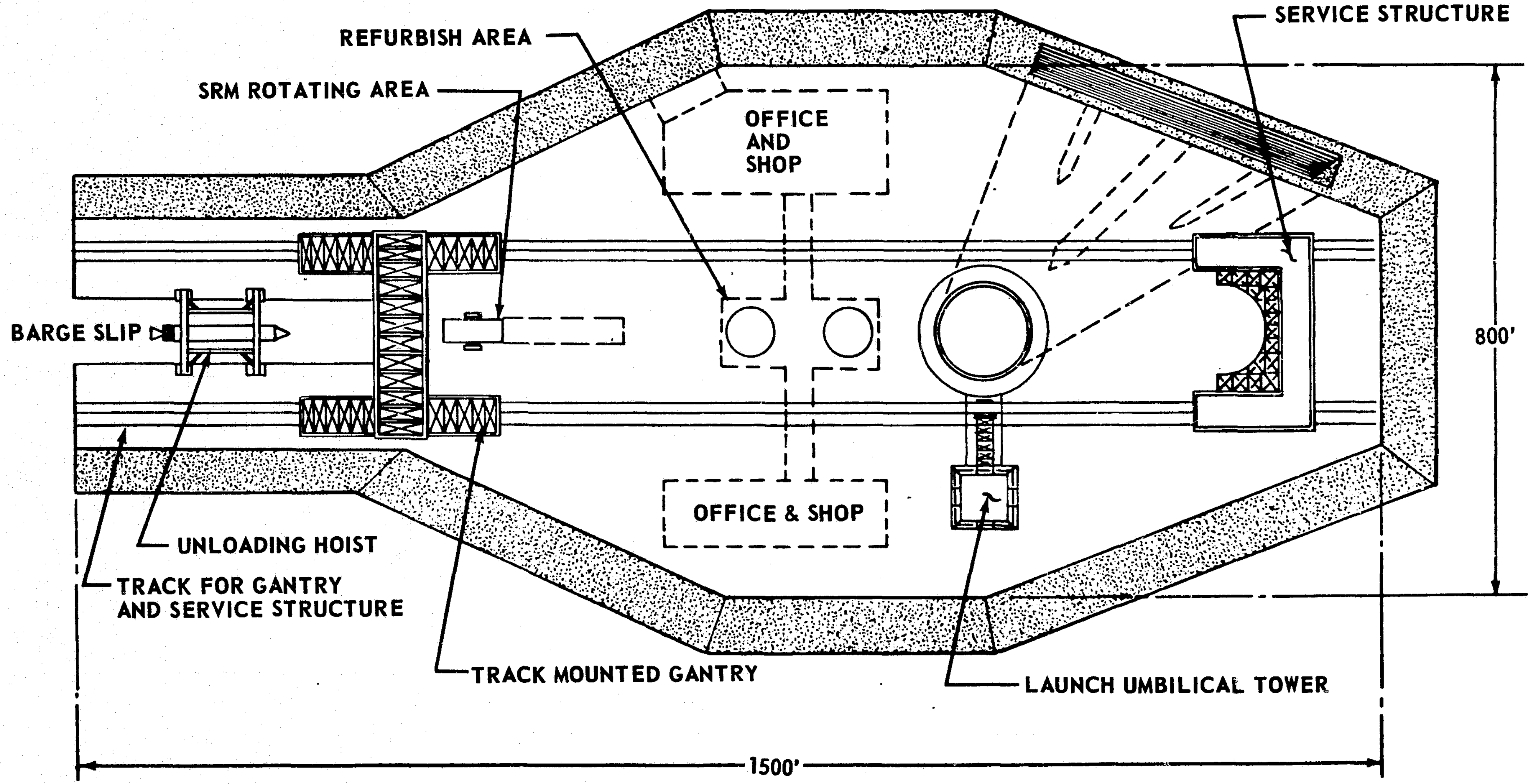


FIGURE 7.3.5.2-1 LAUNCH PAD

7.3.5.2 (Continued)

through static firing, refurbishment, vehicle assembly, test and launch.

The solid rocket motor (SRM) stages will be first hoisted to deck level by the unloading hoist frame, and the entire load attached to the gantry crosshead. The gantry will lift and move the SRM stage to the rotating slip, where the SRM trunnions will be placed in the stage rotating fixture. After rotation into an upright position and with the unloading hoist frame returned to the unloading hoist, the gantry will move the SRM stage to the silo and lower it into position. The gantry will also be used for unloading, transporting and lowering the stages into the silo, or into the subterranean refurbishment areas. The service structure will be moved forward or back under its own power. The launch umbilical tower will be stationary. It will support the launch umbilical swing arms, which will retract to provide clearance as required for vehicle stacking or launch.

The office and shop areas will be completely enclosed within the bulk of the launch pad. The refurbishment areas will have sliding roofs over the stage support rings, which can be opened to permit emplacement or removal of a stage before and after static firing.

7.3.5.3 Launch Pad Cross Section: Launch Umbilical Tower (LUT), Launch Vehicle, Silo and Flume

Figure 7.3.5.3-1 shows the launch vehicle in position and ready for launch. The service tower has been withdrawn and is not visible. The SRM stages are supporting the entire weight of the launch vehicle, and the core support booms have been withdrawn.

The launch umbilical tower (LUT) will be stationary. Even though the service arms retract at launch, the LUT will require some refurbishment after each launch. Not shown are the service arms for the core stage, which can be used either during static firing of the core stages or in launch configuration.

After the SRM stages are in place during vehicle assembly, the core stage will be moved to the launch position and lowered into the silo onto the core support arms, then will be mated with the SRM stages. The payload and injection stages will be joined together while the injection stage is in the refurbishment area after static firing. As a single unit, they will be lifted by the gantry and stacked on the vehicle core stage in the launch position. After vehicle stacking is complete, the service structure will be moved to the vehicle for checkout, servicing and arming of the vehicle.

Flame deflectors will be provided at the vehicle base to reduce launch pad damage. At liftoff the exposed ends of the SRM stage support fixtures are rotated upward into the silo walls, removing exhaust obstructions and reducing launch pad damage. After each launch the launch complex will be refurbished, but this should seldom be necessary after static firing.

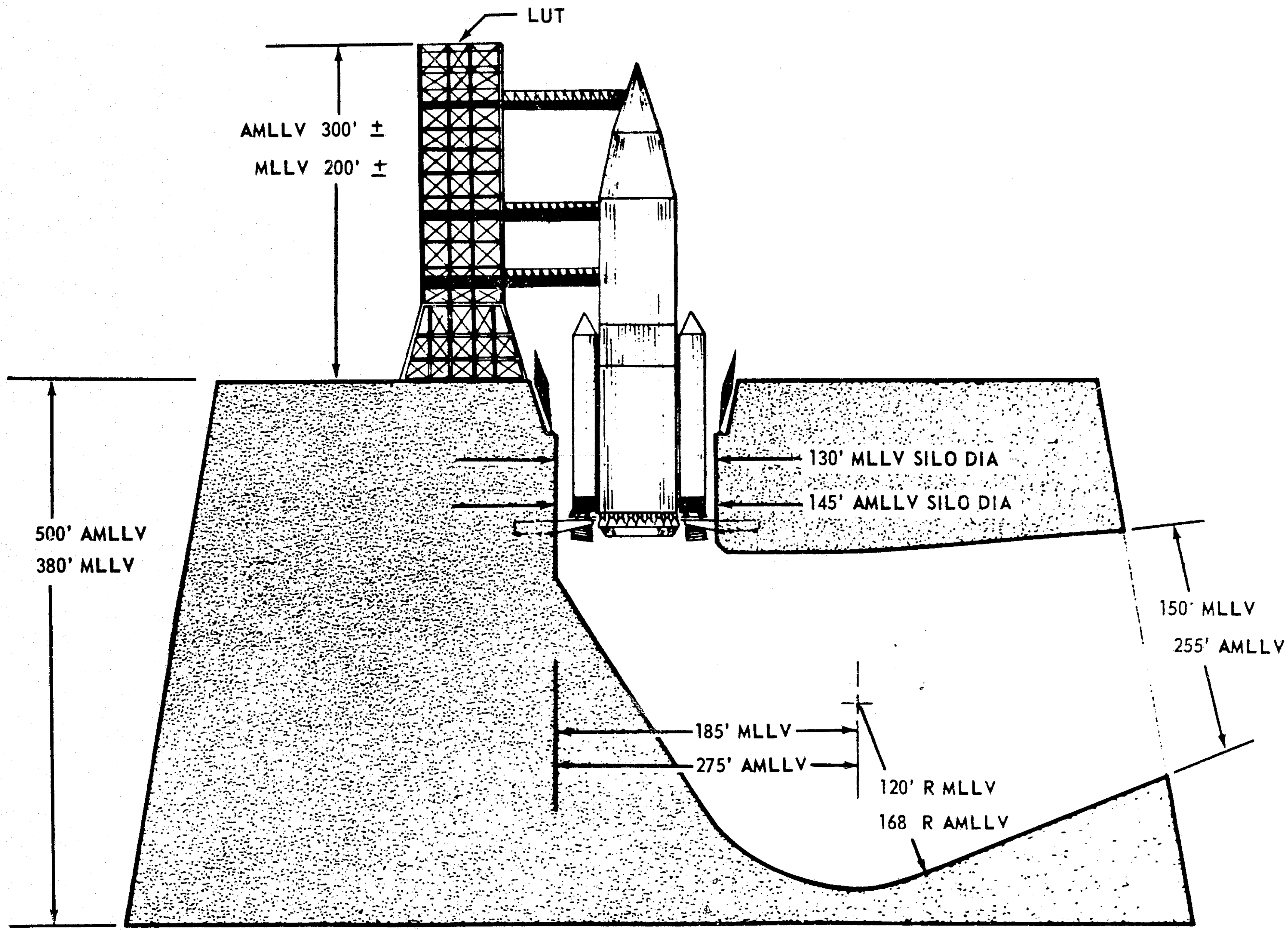


FIGURE 7.3.5.3-1 SECTION - THROUGH LAUNCH PAD SHOWING LUT, LAUNCH VEHICLE AND EXHAUST FLUME

7.3.5.4 Solid Rocket Motor (SRM) Stage Supports

The SRM stages are lowered onto the SRM stage support and alignment fixtures by the overhead gantry as shown in Figure 7.3.5.4-1. Braces are attached to the forward (upper) end of each SRM stage and the alignment support is retracted so that the stage is adjacent to the silo wall. After all SRM stages are in position, the core stage is lowered into the silo from the gantry crosshead. It is then supported initially by the support arms.

Each SRM will then be aligned and mated to the core stage. When all are in position, the support arms to the silo wall will be disconnected from the core stage and rotated out of the way. The entire weight of the core stage will be supported by the SRM stages.

The design of the SRM "support and alignment fixtures" was dictated by these requirements. The SRM stages may be used in various combinations from zero to a maximum of twelve, and they must be mated to the core stage without putting significant loads onto the core. "Roll Ramp Actuators" on the gantry will be used as the final alignment adjustors.

The SRM stage to deck brace (hydraulic alignment boom) will be attached before the gantry hoist is disconnected from the stage. They will be used to position the forward (upper) end of the SRM to the core for attachment, and are removed after the SRM stage is mated to the core.

7.3.5.5 Static Firing Configurations

Main Stage - The main (core stage) is static fired in the launch silo, in the launch position as shown in Figure 7.3.5.5-1. It is supported, and restrained, by the same support arms (booms) which are used for positioning the core while attaching the SRM stages prior to launch. In addition, restraining snubbers will be mounted on the SRM aft supports to maintain core stage alignment. A special counter weight will be lowered into position on top of the core stage, to complete the restraining action required.

The same service arms used in the flight configuration will be used for fueling the core stage for static firing. Pneumatic, hydraulic, power and control lines will connect to the same umbilicals used in the flight configuration. Special provision will be made for additional hard line connections as required.

After static firing is complete, the stage will then be moved to the launch pad refurbishment area. The silo and ground support equipment will be inspected for damage, and refurbished as necessary.

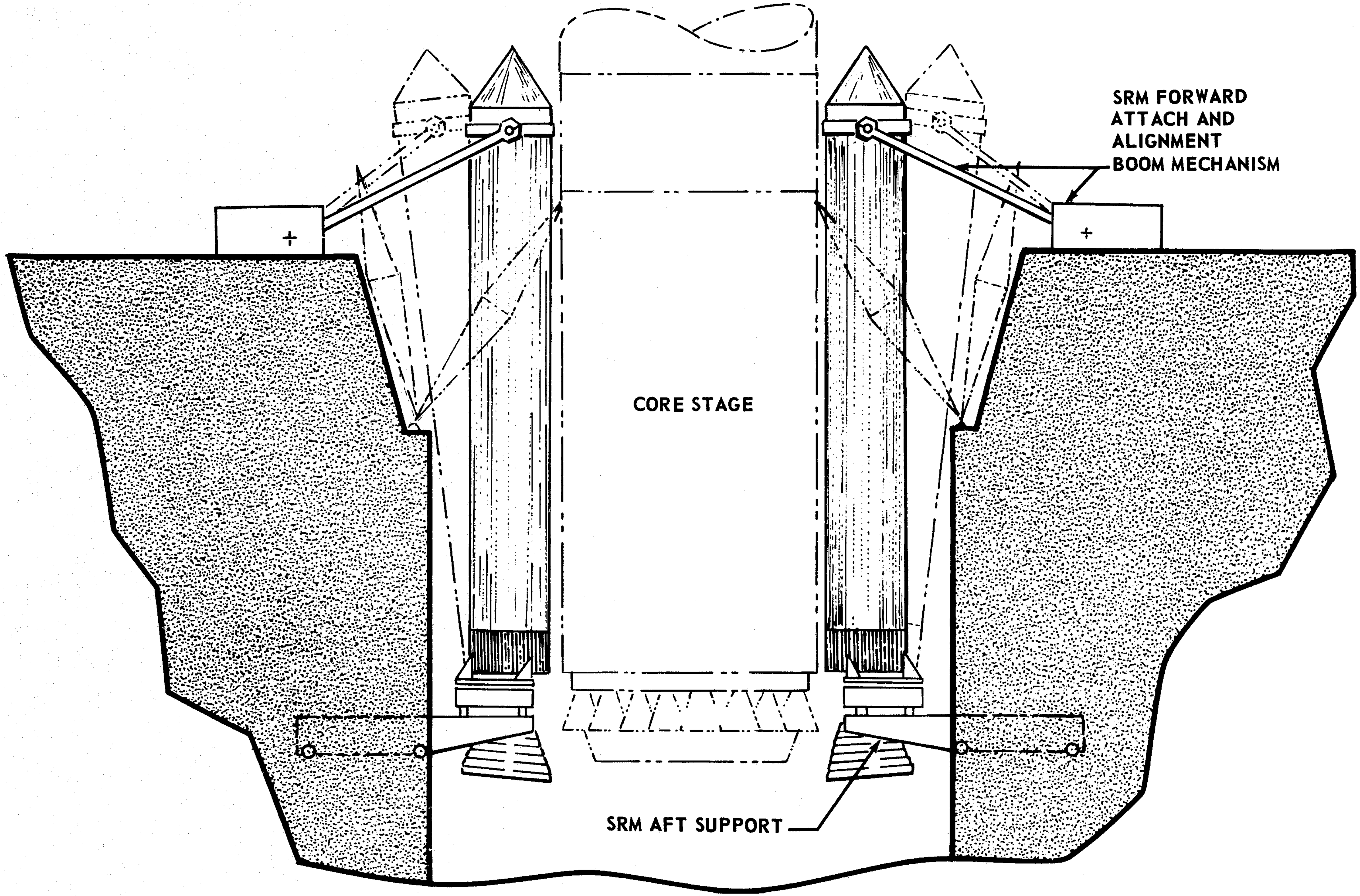


FIGURE 7.3.5.4-1 SECTION - THROUGH SILO SHOWING FORWARD AND AFT SRM SUPPORT

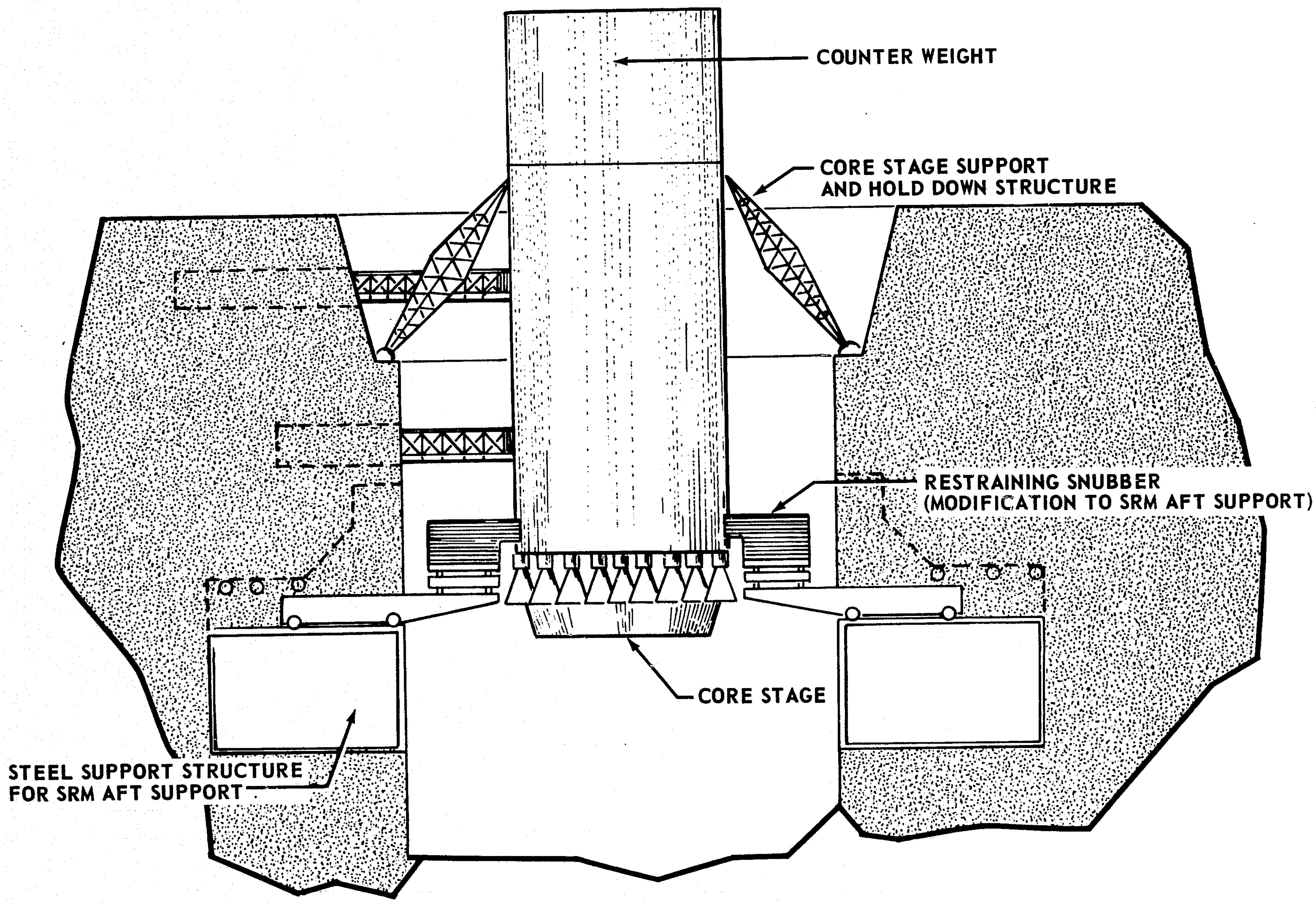


FIGURE 7.3.5.5-1 STATIC FIRING CONFIGURATION

7.3.5.5 (Continued)

Injection Stage - Unlike the main stage, the injection stage cannot be static fired in its normal launch position. Special fixtures and jigs must be designed and made available to support the injection stage in the static firing position, as illustrated in Figure 7.3.5.5-2. Provision for fueling, pneumatic, power and control lines for static firing must be made. There will normally be separate hard line connections, independent of the service and control facilities available for launch.

The restraining snubbers mounted on the SRM stage aft support will be the same used for static firing the core stage. The support and holddown arms are the same that will be used to support the core stage during assembly, or for static firing.

The counter weight will be an elongated battleship stage section, designed so as to give the height for mounting and weight required for holddown. Thus, the base of the injection stage will then be in the same location as the core stage is for static firing or launch.

The injection stage will be removed from the static firing position when testing is complete, and lifted into the refurbishment area for the injection stage. The silo and GSE will be refurbished as necessary, and prepared to receive SRM stages and the core stage for vehicle assembly.

Counter-weight modules can be stored on deck clear of the launch activity when not in use.

7.3.5.6 Barge Docking, Handling Facilities and Equipment

Since the rise and fall of tides along the Florida coast is minimal, barges can be docked and ballastered onto caissons at any time in normal weather. Loading and unloading can then proceed independent of tides. The dimensions on the facility illustrated in Figure 7.3.5.6-1 are sufficient to accommodate barges for the largest size multipurpose large launch vehicle.

Unloading will be done in two stages. The unloading hoist frame will be first lowered and attached, and the article will be raised to the level of the launch pad deck. The removable hoist frame will then be attached to the gantry cross head, and lifting will continue until the load clears the barge slip and can be moved laterally to the rotating pit or launch silo.

The gantry as illustrated moves on rails the length of the launch pad, from the barge slip across and over the refurbishment areas to and beyond the launch silo. Lifting will be accomplished with synchronized Roll Ramp Actuators, allowing for precision positioning of the stages during stage testing and vehicle assembly operation. Sufficient clear span will be provided for the largest loads, and to clear the highest assembled vehicle configurations.

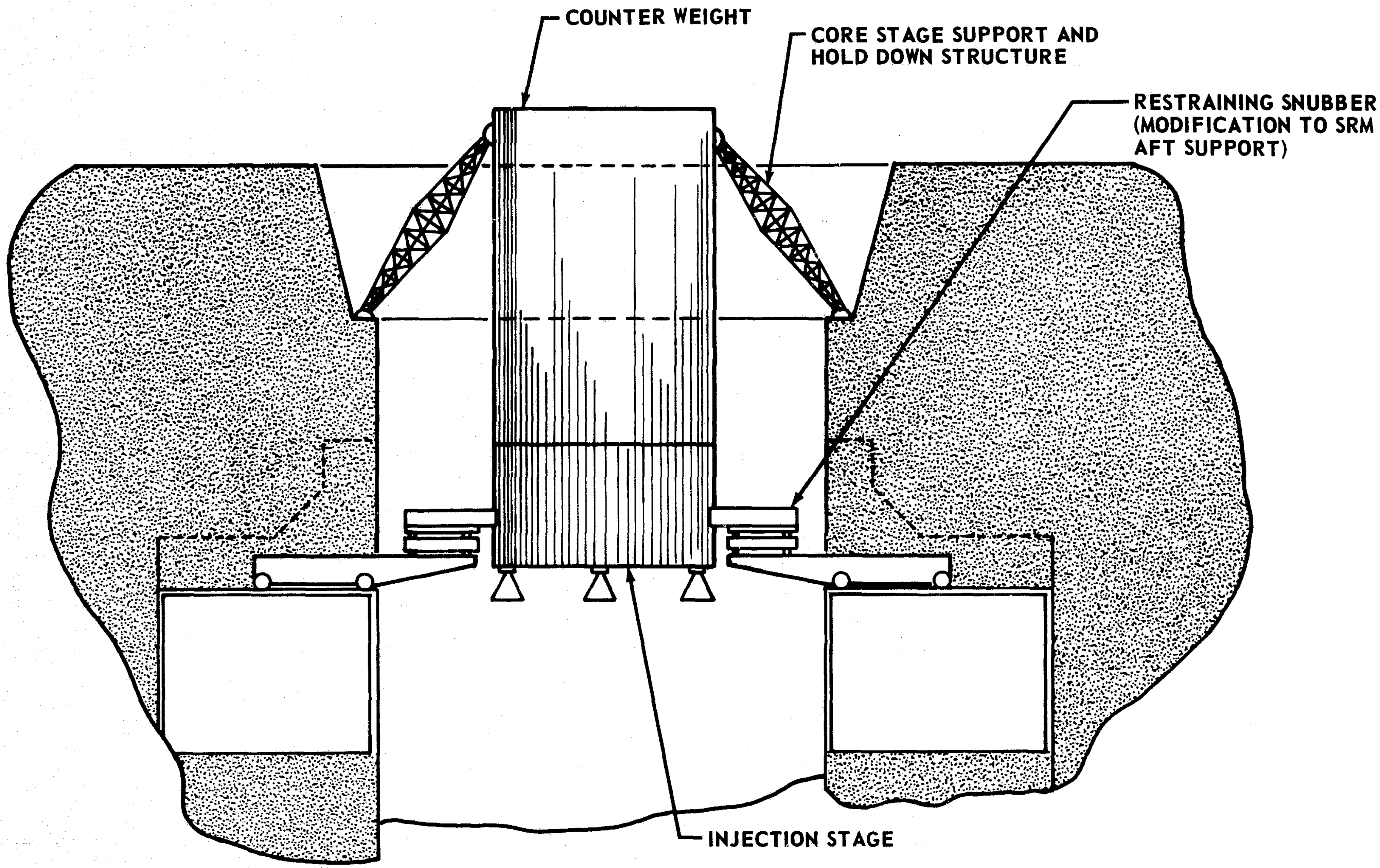
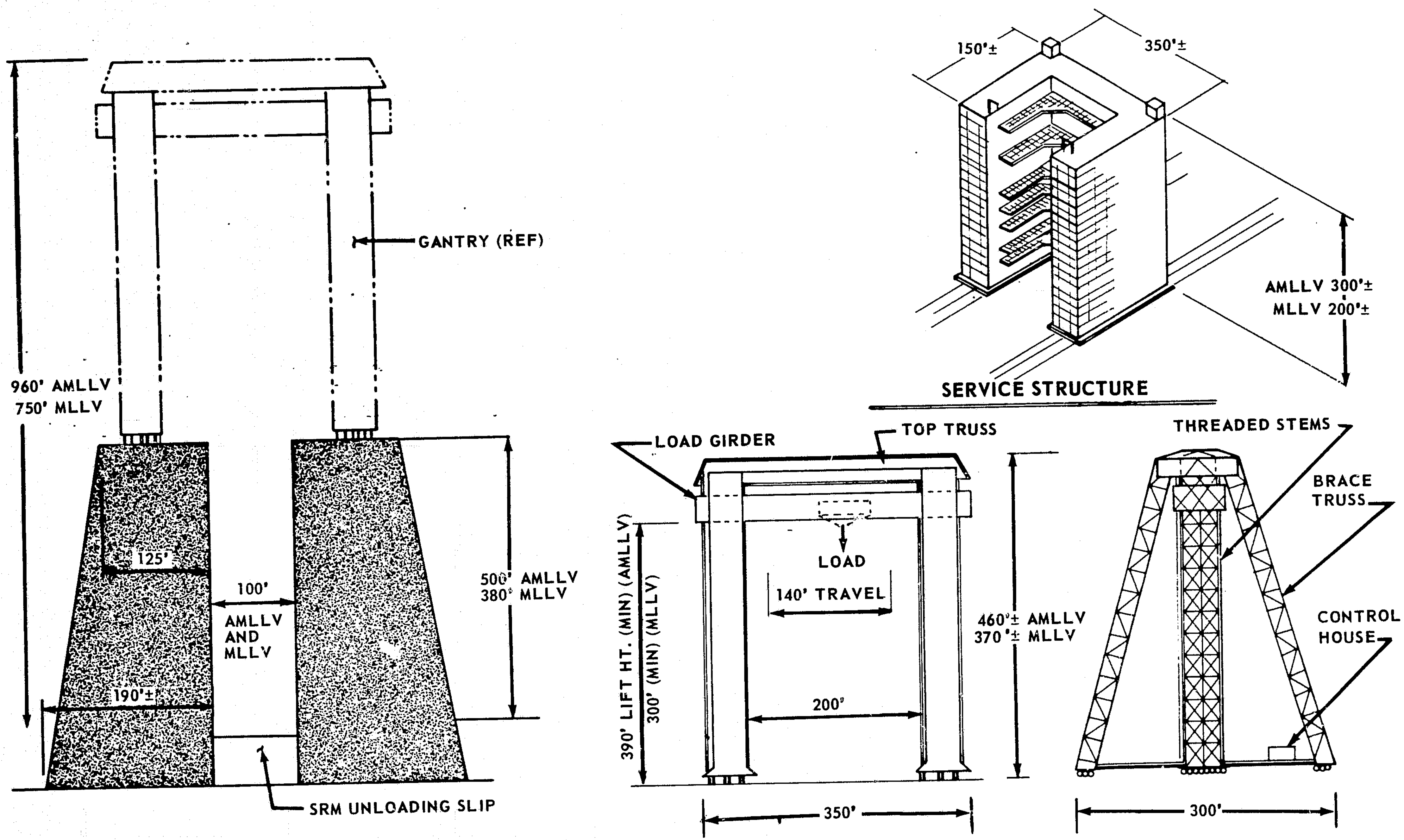


FIGURE 7.3.5.5-2 INJECTION STAGE STATIC FIRING CONFIGURATION



SECTION THROUGH PAD AND SRM
UNLOADING BARGE SLIP

GANTRY ELEVATION & SIDE VIEW

FIGURE 7.3.5.6-1 BARGE DOCKING, HANDLING FACILITIES AND EQUIPMENT

7.3.5.6 (Continued)

The service structure will be stationed on the end of the launch pad opposite the barge slip. It will move forward on rails to service the stacked vehicle, and then be moved back to the limits of the launch structure prior to launch. The support rails will straddle the barge slip, the refurbishment area openings and the launch silo, extending onward to the service tower parking area. These tracks will be used interchangeabley by either structure within the limits of its operation.

7.3.5.7 SRM Stage Aft Support

The SRM stage supports are shown in position in the silo in Figure 7.3.5.4-1. Each is of massive construction, designed to carry static loads up to 6,000,000 lbs. As illustrated in Figure 7.3.5.7-1, the support is mounted on rollers so that it can be moved in or out of the silo wall to position the SRM stages. Upon lift-off at launch, the SRM support ring will rise in an arc, following the movement of the stage until the support ring is pivoted into the clear in the protection of a recess in the silo wall.

When the SRM stage is first lowered onto the aft support, the support will be retracted to bring the SRM stage adjacent to the silo wall. When all SRM stages are in place, the core stage will have clearance to be inserted, and suspended from the core stage support arms. The SRM stages will then move individually forward on the aft supports, as the upper hydraulic booms are extended and positioned. Thus each SRM stage will be mated to the core stage, until all are in place. The core support arms will then be disconnected and retracted, allowing the entire weight of the vehicle to be carried by the SRM stage aft supports.

7.3.5.8 Hoist Lift Frame

The plan for off-loading barges, because of the tremendous heights involved, will be to lift in two stages. The hoist lift frame will elevate the load to the level of the launch pad deck. There the unloading hoist frame will be attached to the gantry cross head, and the gantry cross head will be raised by its roll ramp actuators to the height desired.

As illustrated, in Figure 7.3.5.8-1, the hoist lift frame is also powered by roll ramp actuators to elevate the load from the barge to upper deck level. Note that the hoist frame spanning the unloading slip will be removable from the four synchronized roll ramp elevators.

The threaded lift stems (screws) will be hung vertically, supported from the top and carrying their loads in tension. The lift screws will then be fixed and will not turn. They can be manufactured in short lengths, shipped from the factory and welded together on site to the desired lengths. This is proven technology.

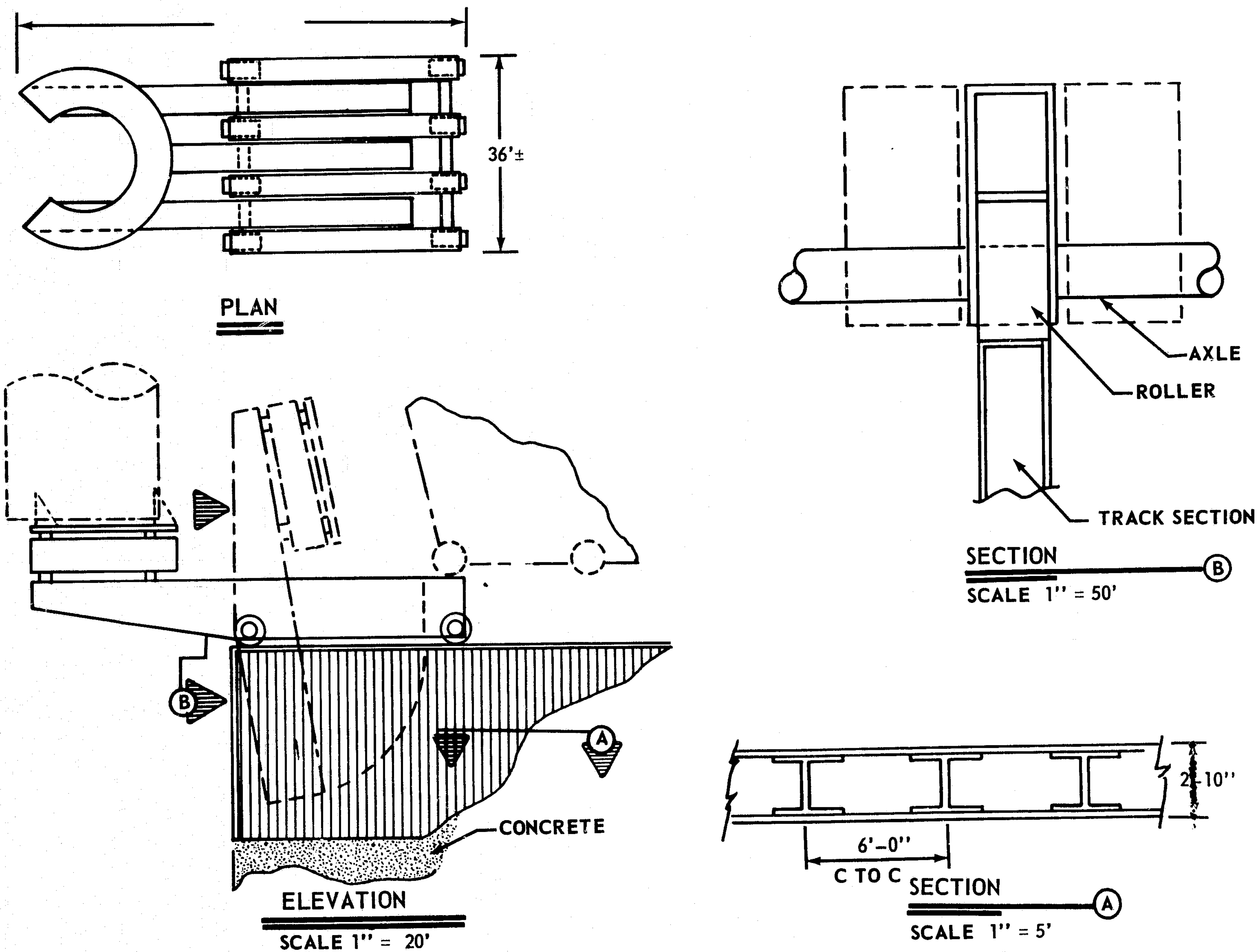


FIGURE 7.3.5.7-1 SRM AFT SUPPORT

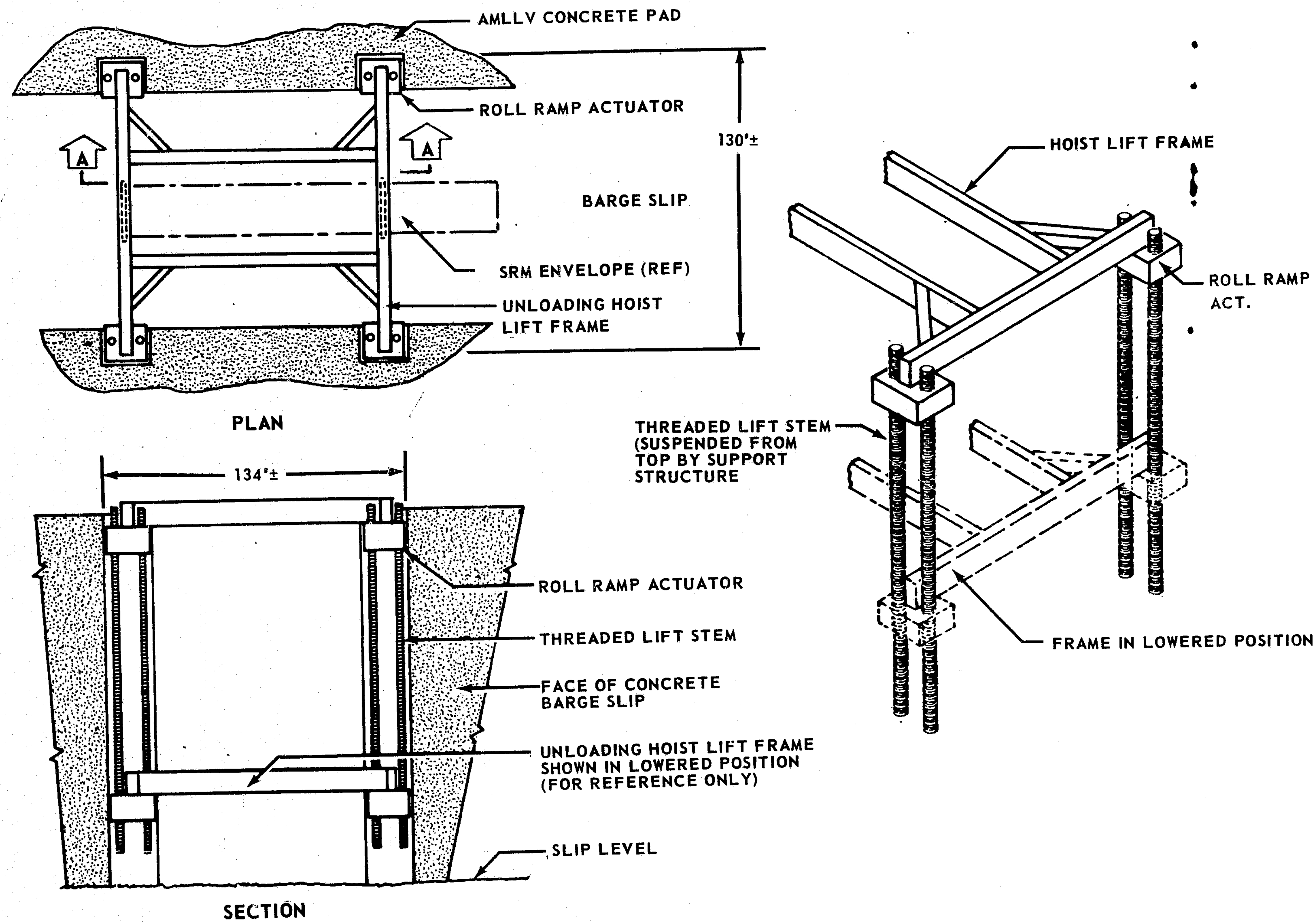


FIGURE 7.3.5.8-1 DETAILS OF HOIST LIFT FRAME

7.3.5.9 Office And Work (Shop) Areas

Figure 7.3.5.9-1 shows a cross section of the launch pad through the refurbishment areas. It does not show the construction of the launch structure, but serves only to illustrate possible locations for office space and shop areas.

The core stage and the injection stage will each be lowered into their respective refurbishment areas after static firing. The retractable roofs will normally be in the closed position, opened only to permit entry or exit of the stages. They will be reinforced to withstand overpressures generated by vehicle launch.

Work platforms will be stationed in the surrounding walls of the refurbishment rooms, to be lowered as required to work on specific stations of the stage.

Stage support rings will be so designed as to provide ready access for men and materials for the task of inspection and refurbishment of the aft stage structures and engines. Horizontal passageways will connect the service, or shop areas to the refurbishment areas. Elevators will be located at strategic intervals to service all levels of the launch complex. The high bay area will be located at ground level, and will be generally used for storage, or for work on outsize structures.

7.3.5.10 Facility and Equipment Resource Requirement Costs

Costs for launch facilities and equipment listed and described in paragraphs 7.3.3 - 7.3.5 have been estimated by Boeing organizations at Huntsville and KSC. Cost information available from NASA and Boeing Saturn V activities was used as a basis for this effort. Table 7.3.5.10-I lists the "get ready" non-recurring costs of facilities and equipment. Recurring annual maintenance costs are estimated and will approximate the same for AMLLV and MLLV. They are:

Brick and Mortar	\$15,840,000
Equipment	\$ 3,960,000

Consideration was given to the costs of a new launch facility for launch of vehicle stages to orbit without strap-ons. Table 7.3.5.10-II tabulates cost estimates for this option.

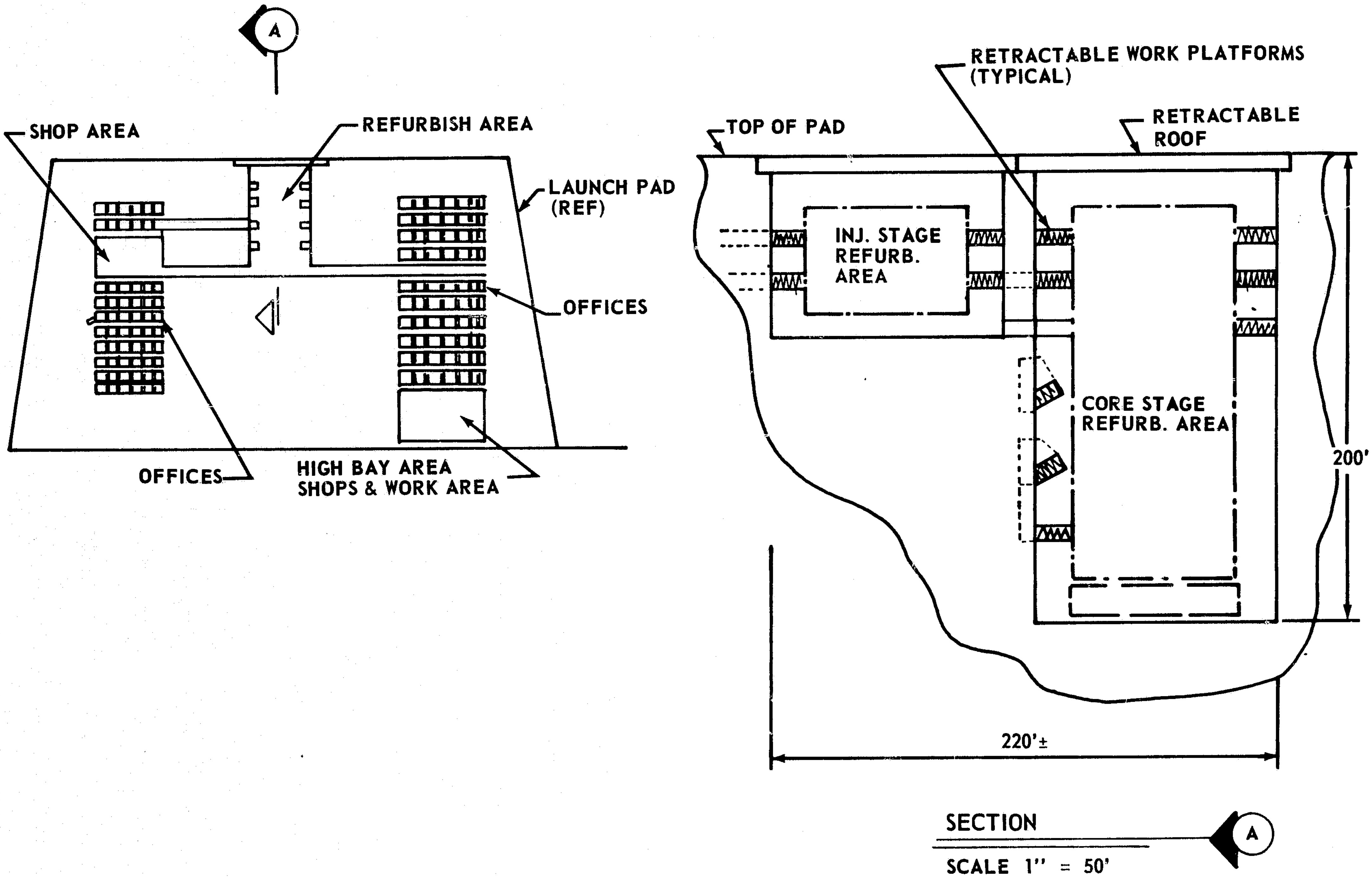


FIGURE 7.3.5.9-1 OFFICE AND WORK SPACE (GENERAL CONFIGURATION)

TABLE 7.3.5.10-I AMLLV/MLLV LAUNCH FACILITIES AND EQUIPMENT COSTS - NON-RECURRING - FOR ALL-UP VEHICLES

ITEM	AMLLV		MLLV	
	BRICK & MORTAR $	EQUIP. COST $	BRICK & MORTAR $	EQUIP. COST $
Site Development Canal, Hyd, Fill, etc.	$ 46,000,000		$ 46,000,000	
Reinforce Concrete Launch Pad (Flame DeflectP	209,440,000		188,500,000	
Gantry Crane	22,610,000		20,349,000	
Unloading Crane	6,545,000		5,891,000	
Service Structure	58,671,000		52,804,000	
Umbilical Tower	14,092,000		12,683,000	
SRM Aft Support Structure	12,896,000	$129,150,000	10,317,000	$129,150,000
SRM Fwd Attach	8,680,000		6,944,000	
Core Support & Holddown Boom	17,112,000		14,545,000	
Propellant Stroage and Transfer and Disposal Sys.	83,250,000	Test Equipment	79,087,000	Test Equipment
Stage Storage Acceptance Test and Checkout	5,000,000		4,250,000	
Launch and Test Control Center	23,800,000		23,800,000	
Off-Site Support Complex	31,613,000	20,184,000	31,613,000	20,184,000
TOTALS	$ 539,709,000	* $149,334,000	$ 496,783,000	$149,334,000

*Includes GSE

TABLE 7.3.5.10-II LAUNCH COMPLEX (NEW) SINGLE STAGE TO ORBIT - AMLLV/MLLV

	AMLLV				MLLV			
	BRICK & MORTAR FIRST COST	EQUIPMENT FIRST COST	BRICK & MORTAR RECURRING $/YR.	EQUIPMENT RECURRING $/YR.	BRICK & MORTAR FIRST COST	EQUIP. FIRST COST	BRICK & MORTAR MAINTENANCE RECURRING $/YR.	EQUIP. MAINT. RECURRING $/YR.
Site Development	$30,000,000				$30,000,000			
Launch Pad	120,000,000				100,000,000			
Gantry Crane	12,000,000				10,000,000			
Unloading Crane	Not Required				Not Required			
Service Structure	45,000,000				40,000,000			
Umbilical Tower	1[illegible],000,000				10,000,000			
* Aft Alignment Fixture	3,000,000	$125,000,000	$14,000,000	$3,500,000	2,500,000	$125,000,000	$14,000,000	$ 3,500,000
SRM Forward Attach	Not Required				Not Required			
Core Support & Hold-On	10,000,000				8,000,000			
Propellant Storage, etc.	83,250,000				83,250,000			
Stage Storage & Checkout	1,000,000				1,000,000			
Launchs Test Control Center	20,000,000				20,000,000			
Support Complex	31,613,000	20,184,000			31,613,000	20,184,000		
TOTAL	$366,863,000	$145,184,000	$14,000,000	$ 3,500,000	$336,363,000	$145,184,000	$14,000,000	$ 3,500,000

*Some method of restraining the main stage is required, but will be somewhat less complex than the SRM Aft Support

7.3.6 AMLLV/MLLV Launch (Less Strap-Ons) From LC-39

A direct comparison of the AMLLV and the MLLV with the standard Saturn V vehicle shows the AMLLV/MLLV vehicle to be longer, heavier during transport, and heavier at liftoff. The AMLLV (without strap-ons) is larger than Saturn V by 120% and the MLLV by 10%, and has 8 million pounds (AMLLV) and 1/2 million pounds (MLLV) greater thrust, respectively.

The civil, structural, electrical/electronic and mechanical aspects of all launch facility structures and support equipment, which will be influenced by the new vehicle parameters, have been evaluated in sufficient depth to ascertain critical modification requirements and to develop the recommended overall facility and operational concept. This section describes briefly the requirements and launch facility concepts established for the AMLLV/ M LLV single-stage-to-orbit launch from a modified LC-39 Launch Complex.

In order to support two equally spaced AMLLV/MLLV launches in a one year period at LC-39, the following quantities of major launch facilities will be required.

One modified VAB High Bay
One Launch Area (existing)
One Injection Stage VAB Low Bay Cell
One new or one modified Mobile Launcher
One Mobile Servicing Structure and park position
One LCC firing room

a. Civil/Structural

1. Siting and Hazards. Modification of existing launch facilities at LC-39 to accommodate the AMLLV/MLLV is feasible; therefore, only those new and modified facilities identified with the handling, transportation, processing, erection and launch of the vehicle will be considered. A new launch pad must necessarily be planned for the AMLLV with SRM stages.

   Because of the greater propellant quantities associated with the AMLLV/MLLV, the peak side-on pressures (psop) at adjacent LC-39 launch areas resulting from a pad incident will be increased from 0.40 psi for the Saturn V vehicle to as much as 0.81 psi. The permanent facilities at the adjacent pad will sustain slight damage due to this increase. It is recommended that schedules be arranged to assure that a vehicle is not in position on the adjacent pad during the hazardous period. Facilities and equipment in the immediate pad area will be completely destroyed by the explosion, and those located around the perimeter of the pad area heavily damaged.

   Protection to the Converter-Compressor Building to withstand higher psop will be provided by reinforced-concrete retaining walls and earth berms. All other LC-39 facilities, including the VAB, will not be adversely affected by the increased explosive hazards.

7.3.6 (Continued)

2. Vertical Assembly Building. One of the three outfitted VAB High Bays will require modification to fulfill the requirements of the AMLLV/MLLV program. The modification will consist of relocating five extensible platforms, along with modification to the floor and roof openings in platform B and major rework of platform A. Platform A is raised to level 425' - 0" roof elevation, which is the maximum level for platform positioning provided in the VAB design. The payload on the vehicle is shorter than the Apollo payload. This decrease in length coupled with the restrictions on maximum positioning level for platform A creates an over-lap of platforms A and B. It is, therefore, concluded that platform A will require extensive rework involving shortening of the platform height as well as new wall penetrations, and increasing the openings in the floors and roof. Platform B requires changes to floor and roof openings.

3. Mobile Servicing Structure. The MSS requires a height extension to permit platforms to be raised to the required level to serve. In order to provide this increased height, considerable structural reinforcement would be required and personnel elevator runs increased, as well as the counter-weight runs. The shortened payload creates problems with fitting the platforms in at their proper levels, and would require extensive modification and replacement of platforms with a newly designed configuration.

4. Launch Area. The increased size, weight and thrust of MLLV increases the rebound loads and reactions to the mobile launcher (ML) supports. In order to accommodate these effects, it is necessary to reinforce the ML support piers and pad structure, provide heat shielding for pad mounted equipment and structure, upgrade the flame deflector anchorage, and increase the HP gas and propellant storage capacities. A new launch pad will be necessary to launch the AMLLV, and existing launch pad modification will be planned only if the MLLV configuration is adopted.

   The exhaust mass flow for the MLLV represents an increase over the mass flow from the standard Saturn V vehicle. The present flame trench dimensions cannot accommodate the exhaust gases without overflow onto deck areas, pad towers, equipment, and support mechanisms without auxiliary deflector shields and ablative coatings.

   The increased demands of the AMLLV/MLLV require a new building having approximately 3500 sq. ft. of floor area for HP gas bottles. This structure will be located on the east side of elevated pad structures in vicinity of present storage facilities. Also new support towers, foundations, and revetment extensions are required at the LOX and LH_2 storage areas to support and protect the new storage vessels.

7.3.6 (Continued)

5. Utilities, Roads and Crawlerway. Additional quantities and flow rates of industrial water are required by the AMLLV/MLLV; however, these increased demands may be easily met by increasing pumping capacity and upgrading the hydro-pneumatic system. The water mains serving the pad area are adequate without modification. Existing electrical power and communications systems are satisfactory and need not be modified.

   Vehicular roads between the docking area and VAB and the access/ service road adjacent to crawlerway are satisfactory for the liquid stage transporters. A new crawlway road bed will be required into the AMLLV launch area.

   The critical loads imparted to the crawlerway by the crawler-transporter carrying the modified MLLV service structure are increased approximately 11 percent over existing. The slight increase in crawlerway settlement under road is easily tolerable and requires no modification. A new service structure with crawlway facilities will be needed for the AMLLV.

b. Mechanical

1. Mobile Launcher (ML). One new (for AMLLV) or one modified ML (for MLLV) may be required. The principal required modifications would involve relocation of all umbilical arms, shielding of the front umbilical tower face, an increase in elevator run, an increase in the ML platform exhaust opening, strengthening of ML platform structure, replacement of the existing vehicle support arms and relocation of equipment in the umbilical tower and ML platform.

   Relocation of swing and access arms also requires that all of the service lines and cables associated with the arms be extended and that equipment on the umbilical tower platforms serving the arms be moved. Strengthening of tower framing members will also be required. Pockets will be provided for swing arm protection. The elevator run will be increased by relocation of the elevator machinery room.

   The exhaust opening in the ML platform is increased in size to provide adequate clearance. Strengthening of the platform structure in the vicinity of the opening is required due to increased rebound loads and new vehicle support conditions. New flame shields and ablative coatings are required on the ML deck in the vicinity of the vehicle. The new vehicle support arms are located on girders which cantilever from the sides of the exhaust opening, and extend upward to a height sufficient to support the vehicle at the forward thrust structure attach points. Protection from exhaust impingement on the bottom of the ML is required because of the plume spread in the trench.

7.3.6 (Continued)

2. Crawler-Transporter. The MLLV is heavier in its transporter condition than Saturn V. Roadway bearing loads increase over those imposed by the Saturn V vehicle. The maximum load per corner on the crawler is due to the new MSS and represents an 11 percent increase over the present maximum corner loads.

3. The Saturn V has a LOX capability of 4,331,843 pounds. The MLLV system requires 4,760,000 pounds of LOX. The LC-39 LOX system has a load capable of holding 900,000 gallons (8,577,000 pounds). Therefore, the LOX capability is adequate.

   The Saturn V has a LH_2 capability of 203,895 pounds. The MLLV system requires 790,000 pounds of LH_2. The LC-39 LH_2 system has a tank capability of 850,000 gallons (502,350 pounds). To allow adequate tank capability, the tankage must be increased by 1,200,000 gallons.

   The existing industrial water system at the pads must be modified to provide additional cooling water to counteract the more severe heating effects produced during a launch operation. The heating effects are partially reduced by the high thrust to weight ratio, but additional water is still required. The maximum flow rate will be increased during the most severe heating period. The same modification will be made on the new ML to provide the additional flow to the deck and umbilical tower.

4. Handling and Transportation. AMLLV and MLLV stages are longer and heavier than the corresponding Saturn V stages. Handling equipment which remains within the VAB will require some modification.

5. Flame Deflector. New wedge flame deflectors are required to dispose of the exhaust. These deflectors will be longer and wider than the present Saturn V deflectors, with side walls running the entire length of the deflector. In addition, flame shields will be provided to protect the upper edge of the pad-flame trench.

c. Electrical/Electronic

One of the three LCC firing rooms will be modified by the addition of new display and control equipment. Display and control equipment for the changed airborne systems and the propellant loading system are modified to be compatible.

One new ML may be required needing the electrical equipment required by the AMLLV. The one modified ML (MLLV) will have the cabling on its umbilical tower modified by additions and rerouting because the UT's umbilical arms

7.3.6 (Continued)

are elevated. Existing ground system equipment is modified to be compatible with changes to launch vehicle systems.

The VAB high bay cell and launch pad will require a small amount of modification to their electrical systems.

d. Table 7.3.6.0-I lists the major facility and equipment costs for new and modified items required for launching the AMLLV or MLLV single-stage-to-orbit vehicle from Launch Complex No. 39 at KSC.

TABLE 7.3.6.0-I MODIFIED LC-39 - FACILITY & EQUIPMENT COSTS
(SINGLE STAGE TO ORBIT VEHICLE ONLY)

	COST - DOLLARS IN THOUSANDS	
	AMLLV	MLLV
LAUNCH PAD	$ 56,000 X	$ 1,000
ROADBED (CRAWLWAY)	19,000 X	No additional cost
RAMP FOR CRAWLER	9,000 X	No additional cost
MOBILE LAUNCHER*	51,000	51,000
MOBILE SERVICE STRUCTURE	19,000 X	17,000 X
VAB MODS.	400	400
FIRING ROOM	52,000**	52,000**
H. P. GAS AND HYDROGEN FACILITY	1,500	1,000
	$207,900	$122,400
MAINTENANCE COSTS	$ 10,000,000 PER YEAR	

X = New Items

*STAGE PECULIAR GSE = $17,000

PAD & LCC EQUIP. = 35,000

TOTAL $52,000

**If a new Mobile Launcher is required, the cost will be $101,000,000

8.0 SCHEDULE PLAN

The objective of the Schedule Plan is to integrate all the sequential flow time lines and schedules into a master program schedule. For each of the previously discussed plans, (Section 3.0 through 7.0) sequential flow time lines or schedules were constructed. As a guide for this activity, a Project Phase Relationship chart that described a 6 year program was prepared for review by the Boeing groups participating in the study. When their inputs were received and collated, it was found that the overall relationship and schedule had to be extended to an 8 1/2 year program, from authorization to proceed through launch of the second R&D flight vehicle.

It was found that the production and sequencing of the facilities "F" vehicle through the post manufacturing test and checkout cell, the dynamic test stand and the launch complex was the critical factor in developing the minimum time schedule. The final output of this plan preparation resulted in the Master Program Schedule presented in Figure 8.0.0.0-1.

The output of the schedule plan is used to determine if the program as costed is reasonable in terms of meeting the launch rate of two vehicles per year. The schedule appears tight with regard to the turn-around-time (launch to launch at the launch site). Study results show that 32 weeks are required for the turn-around. There is some lost time at the beginning and end of launch complex operations (refurbishment of the launch pad could be taking place at the same time the next vehicle is being readied for placing in the silo). This would reduce the turn-around-time to 29 1/2 weeks.

Experience on the Saturn V program has shown that time lines can be reduced as (1) confidence is acquired that reduced testing will be acceptable, (2) refurbishment times are reduced, (3) tasks are accomplished in less time by operating in parallel modes and using experienced personnel.

The following paragraphs are excerpts from the previous plans, and although redundant, are provided to summarize all time line and schedule information produced during this study effort.

8.1 DESIGN SCHEDULES

The functions accomplished during the design phase are (1) design of the vehicle, (2) planning the integration and operations activities, (3) planning and monitoring the R&D programs, (4) revising the design with data from the R&D tests, and (5) providing sustaining engineering for the production (recurring) program. The schedule is shown in Figure 8.1.0.0-1.

Office facilities existing at Michoud, Louisiana were considered to be adequate for the engineering design activity; therefore, no facility preparation schedule is required.

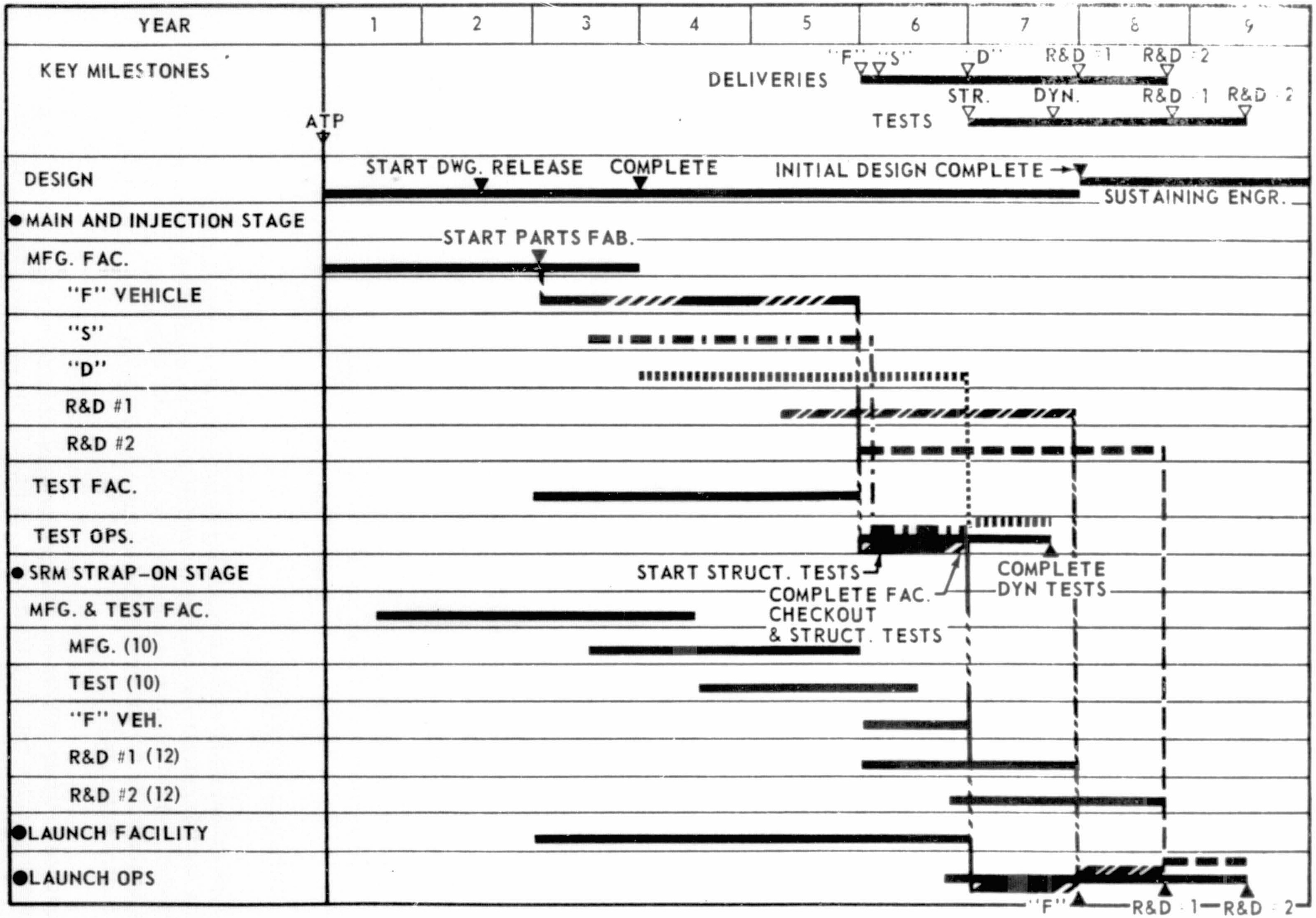


FIGURE 8.0.0.0-1 MASTER PROGRAM SCHEDULE

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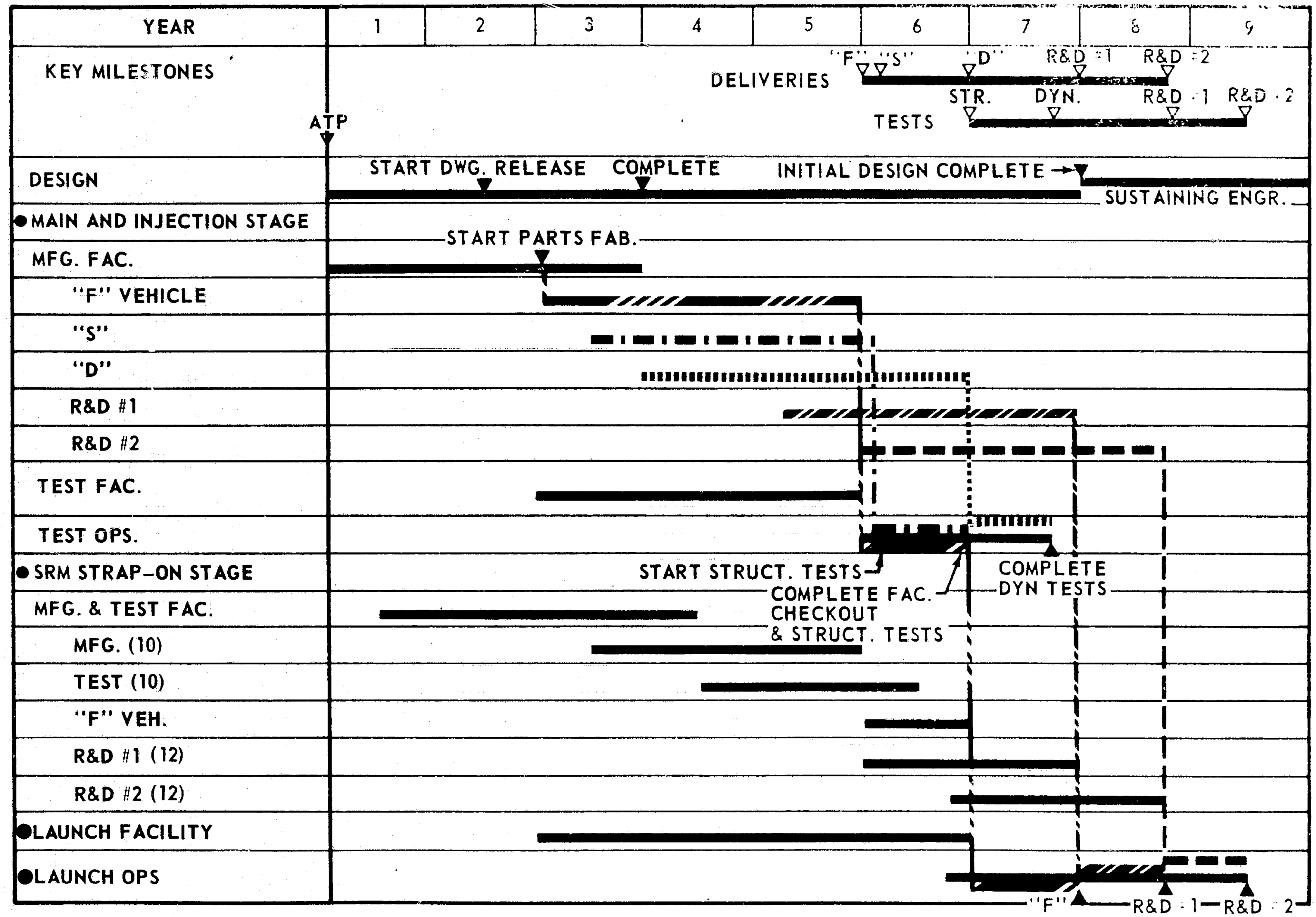
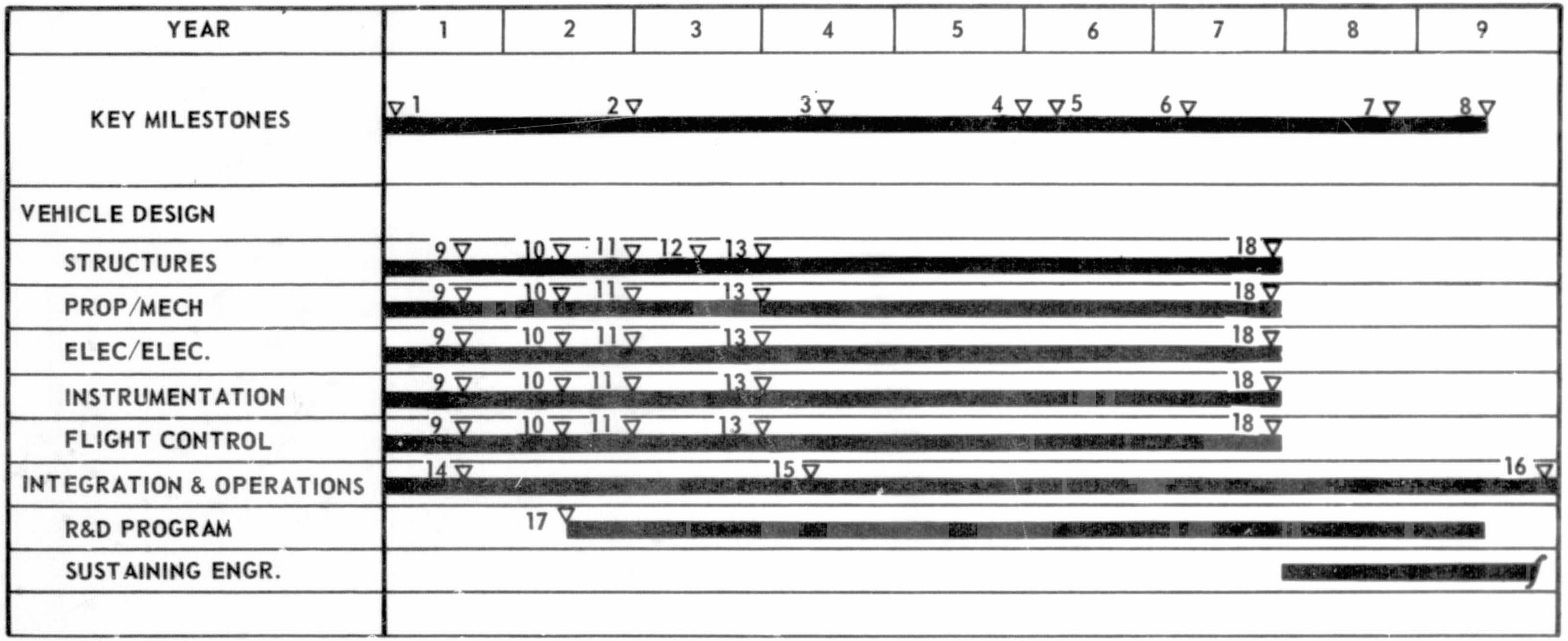


FIGURE 8.0.0.0-1 MASTER PROGRAM SCHEDULE



▽ 1 AUTHORIZATION TO PROCEED	▽ 8 2ND R&D LAUNCH	▽ 15 PLANS FINALIZED
▽ 2 START DETAIL PARTS FAB.	▽ 9 SPECIFICATION RELEASE COMPLETED	▽ 16 DRAWINGS FINALIZED WITH RESULTS FROM R&D PROGRAM
▽ 3 START "F" VEH. ASSY.	▽ 10 RELEASE OF COMPONENT DRAWINGS INITIATED	▽ 17 PLAN AND MONITOR R&D TESTS
▽ 4 "F" VEH. THRU POST/MFG. T&CO.	▽ 11 SYSTEM PERFORMANCE ANALYSIS COMPLETED	▽ 18 MODIFICATIONS OF R&D VEHICLE COMPLETED
▽ 5 "DTV" VEH. AVAILABLE	▽ 12 STRENGTH CHECKS COMPLETED	
▽ 6 R&D TESTS (EXCEPT FLIGHT)	▽ 13 INITIAL DRAWING RELEASE COMPLETED	
▽ 7 1ST R&D LAUNCH	▽ 14 TEST REQUIREMENTS DEFINED	

FIGURE 8.1.0.0-1 ENGINEERING SCHEDULE

8.2 DEVELOPMENT AND TEST SCHEDULES - AMLLV/MLLV

The development and test program discussed herein is that testing which is required above and beyond the recurring test activity of the production program. This program is assumed to end with the flight of the second flight test vehicle, for purposes of this costing study.

a. The major tests that have been identified for this program include:

1. Model tests
2. Manufacturing mockup
3. Static load tests
4. Breadboard
5. Dynamic tests
6. Engine development and qualification tests
7. Miscellaneous development tests
8. SRM stage development and qualification tests
9. Flight tests (2) of the maximum size vehicle
10. Ground support equipment
11. Launch vehicle ground support equipment

b. Facilities required for the test program include:

1. Shops and laboratory (for component and subsystem development tests)
2. Static test stand
3. Dynamic test stand
4. Wind tunnels
5. Launch complex
6. Transportation facilities (considered in paragraph 8.4.)
7. Cast, Cure and test facilities for SRM

8.2.1 Main Stage, Injection Stage and SRM Strap-On Stage Attachment Structure

The test schedule for the main and injection stages is shown in Figure 8.2.1.0-1. Because the SRM strap-on stage attachment structure are required for the SRM PFRT program, the structural load testing for these articles must be completed early. Flag note 16 shows that the testing must be complete in the latter part of the third year. This is feasible because the components will be fabricated in existing Michoud facilities. Schedules for fabrication of the new main and injection stage test facilities required for this program are shown in Figure 8.2.1.0-2.

Because existing facilities for wind tunnel tests and component and subsystem development tests are available, no schedule time for facility activation is required for these items.

8.2.2 SRM Strap-On Stage

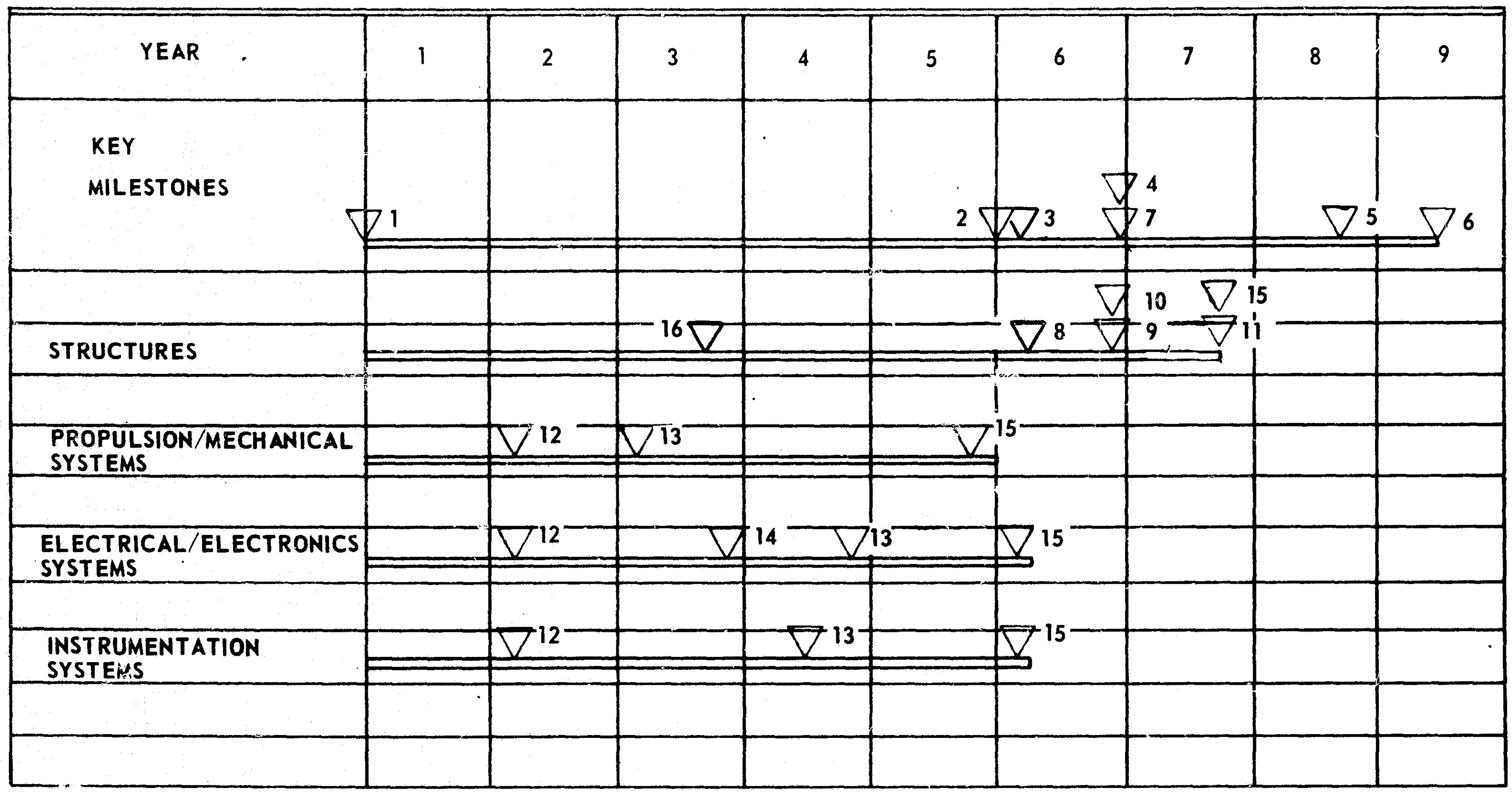
Master strap-on stage phasing and test schedules were prepared by Aerojet General Corporation and are presented in Figures 8.2.2.0-1 and 8.2.2.0-2. Although the phasing schedule is prepared for the MLLV program it is also applicable to the AMLLV program. The only difference is the requirement for additional cast and cure pits for production of solid rocket motors after completion of the PFRT tests.

8.2.3 Liquid Engines

Pratt and Whitney Aircraft prepared detailed schedules for a total engine development program based on experience gained in the RL-10 program. The overall program schedule is summarized in Figure 8.2.3.0-1. A discussion of this program and the detail schedules appear in paragraph 4.2.8 "Engine Development and Qualification Tests" of this document. The original input received from Pratt and Whitney is contained in Volume IX, Propulsion Data and Trajectories' (CONFIDENTIAL), Appendix A. The original input, in itself, is not classified.

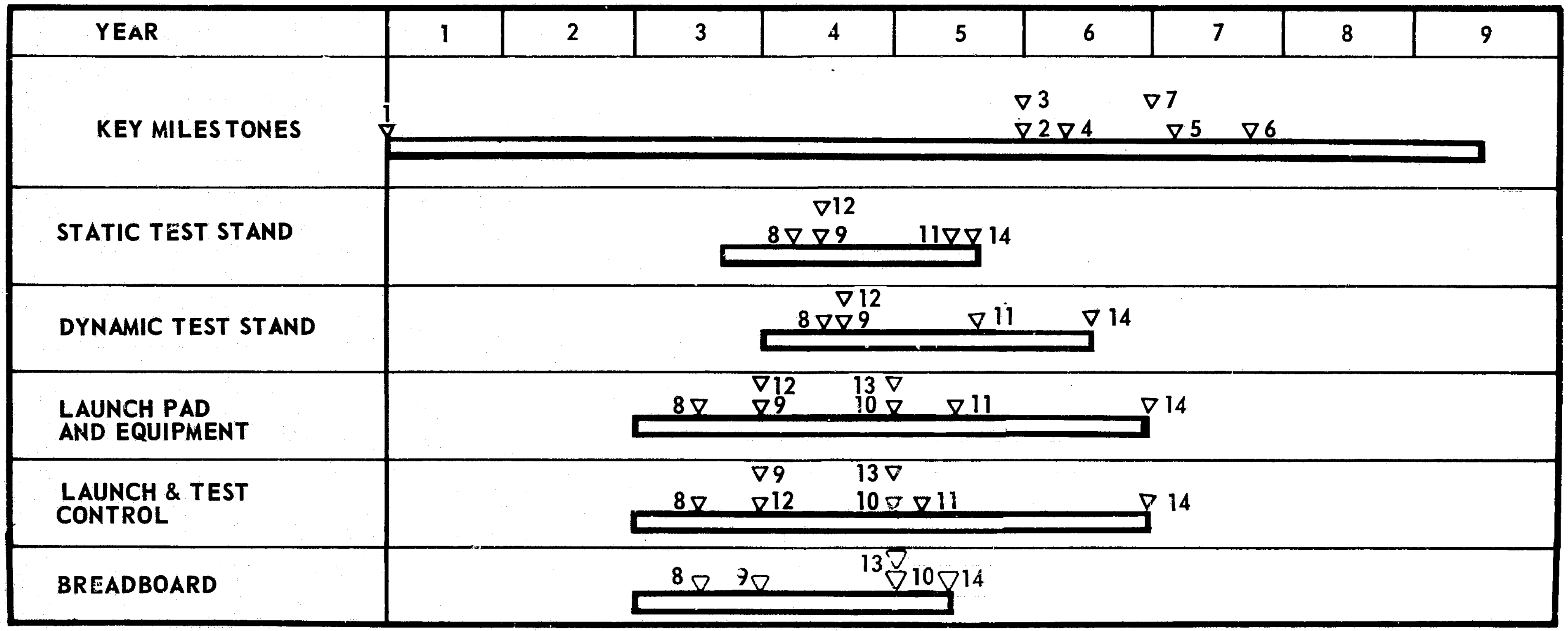
8.3 MANUFACTURING SCHEDULES

Detail manufacturing plans were prepared for main and injection stages of the study vehicle. From these plans the time line sequential flows, as shown in Figure 8.3.0.0-1, Sequential Flow Timeline for Stage Assembly, were prepared for the stage assembly sequence. This data becomes more meaningful when combined with the key program milestones as shown in Figure 8.3.0.0-2, Main and Injection Stage Manufacturing Schedule. Eighteen months have been allowed for component parts fabrication. Start of this manufacturing is paced by facilities, parts design, tool design and tool fabrication. There is a small overlap between start of fabrication and completion of the facility as shown in Figure 8.3.0.0-3. This small overlap will be discussed below. Although the time line shows a normal flow of 16 months for assembly and post manufacturing checkout of the main stage (the



1. AUTHORIZATION TO PROCEED
2. "F" VEHICLE TO CHECKOUT OF DYNAMIC TEST STAND
3. "S" COMPONENTS COMPLETE
4. START DYNAMIC TESTS
5. 1ST R&D LAUNCH
6. 2ND R&D LAUNCH
7. "F" VEHICLE TO CHECKOUT OF LAUNCH PAD
8. START STATIC LOAD TESTS
9. START DYNAMIC TESTS
10. COMPLETE LOAD TESTS
11. COMPLETE DYNAMIC TESTS
12. SPECIFICATION RELEASE COMPLETE
13. VENDOR QUAL. TESTS COMPLETE
14. DEVELOPMENT TESTS COMPLETE
15. QUALIFICATION TESTS COMPLETE
16. COMPLETE LOAD TESTS ON SRM STAGE COMPONENTS

FIGURE 8.2.1.0-1 TEST SCHEDULE - MAIN STAGE, INJECTION STAGE AND SRM STRAP-ON STAGE ATTACHMENT STRUCTURE



▽ 1 AUTHORIZATION TO PROCEED	▽ 8 DESIGN CRITERIA COMPLETE
▽ 2 "F" VEHICLE AVAILABLE	▽ 9 DESIGN 30% COMPLETE – CONSTRUCTION START
▽ 3 "S" VEHICLE AVAILABLE	▽ 10 DESIGN COMPLETE
▽ 4 "DTV" AVAILABLE	▽ 11 CONSTRUCTION COMPLETE
▽ 5 1ST R&D VEHICLE AVAILABLE	▽ 12 LONG LEAD EQUIPMENT ORDERED
▽ 6 2ND R&D VEHICLE AVAILABLE	▽ 13 STANDARD EQUIPMENT ORDERED
▽ 7 "F" VEHICLE AT LAUNCH PAD	▽ 14 EQUIPMENT INSTALLED AND CHECKED OUT

FIGURE 8.2.1.0-2 TEST AND LAUNCH FACILITIES - BRICK AND MORTAR AND EQUIPMENT

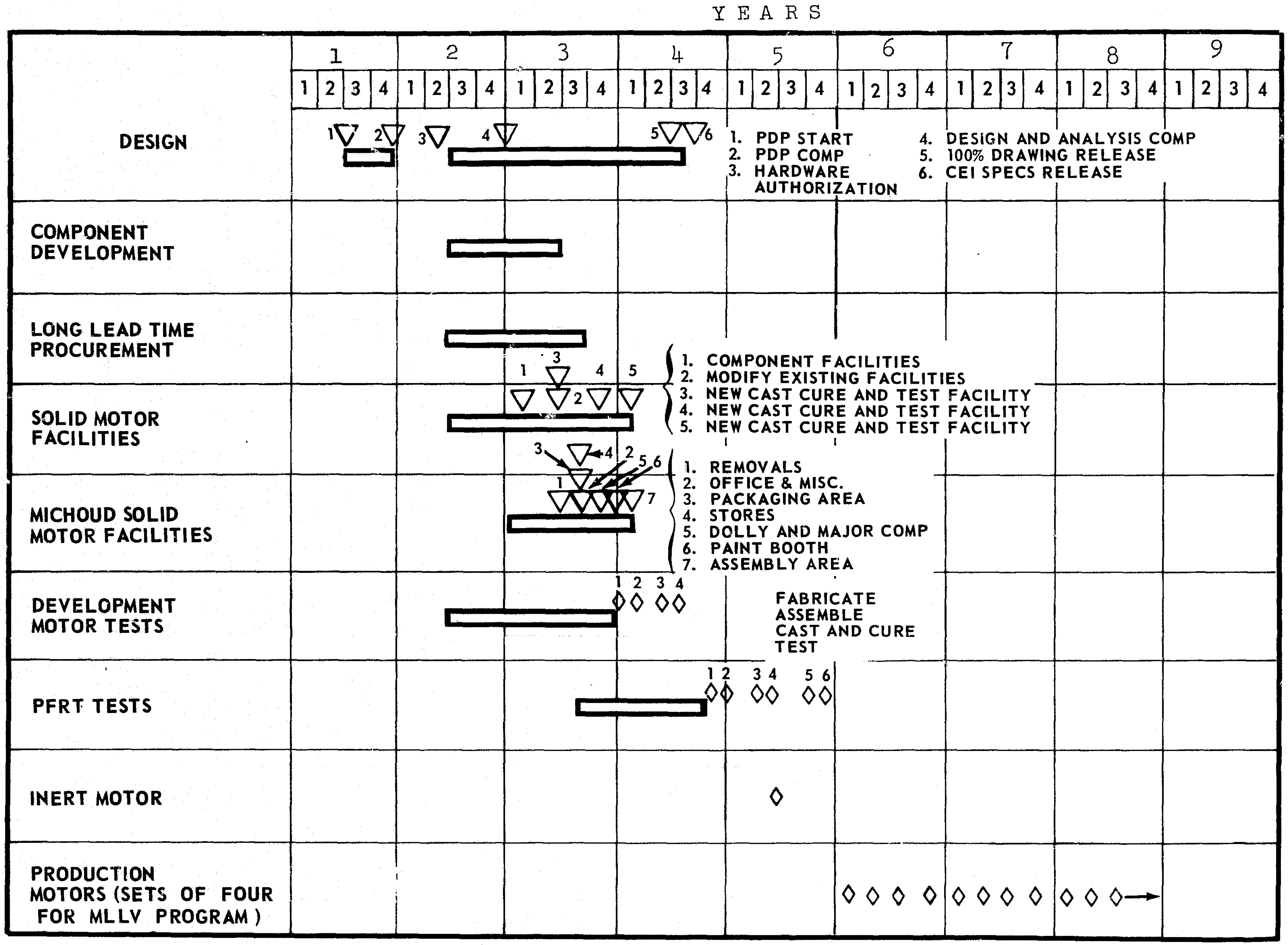


FIGURE 8.2.2.0-1 MASTER PHASING - SOLID MOTOR STAGE

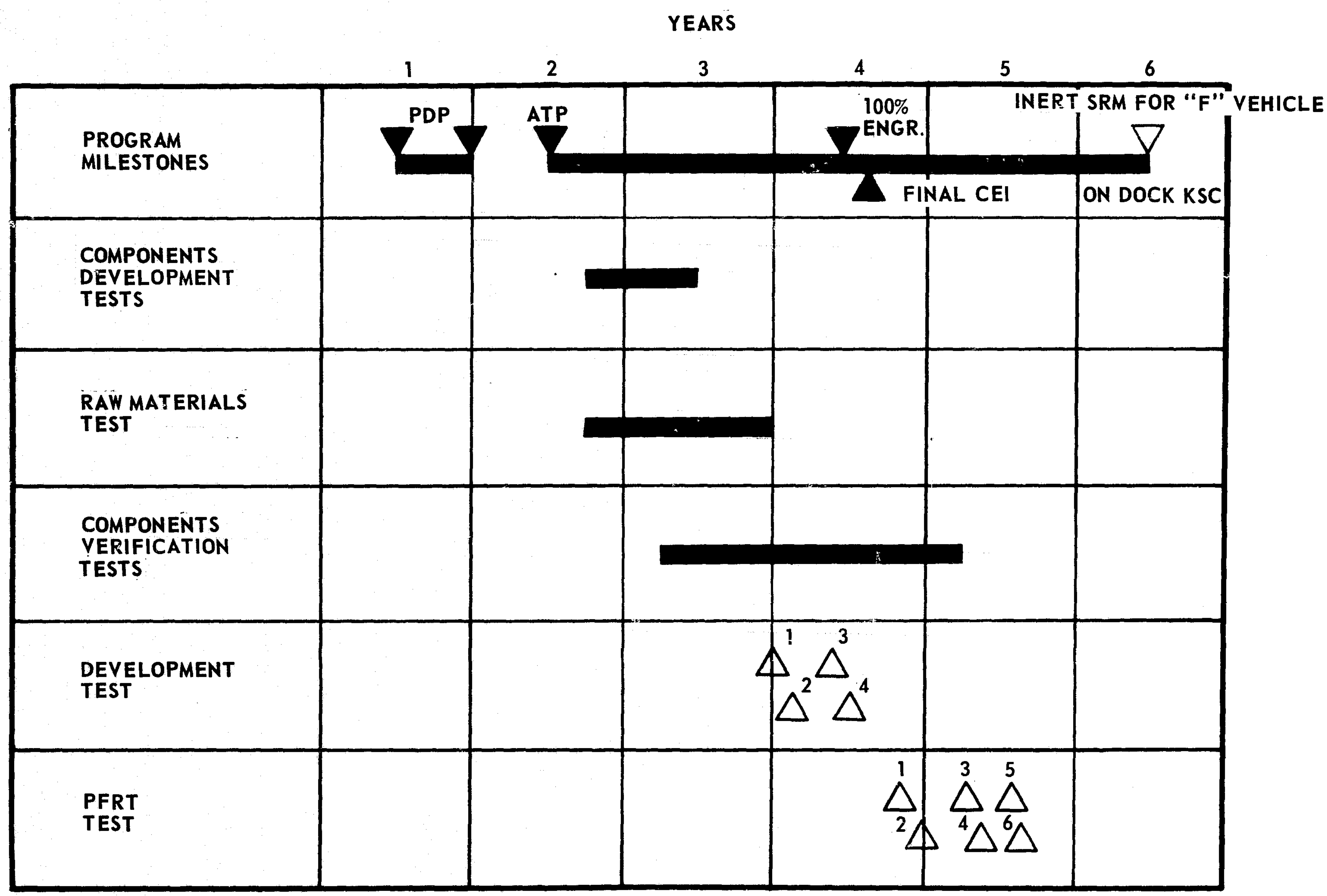


FIGURE 8.2.2.0-2 TEST SCHEDULE - 260" SRM STAGE

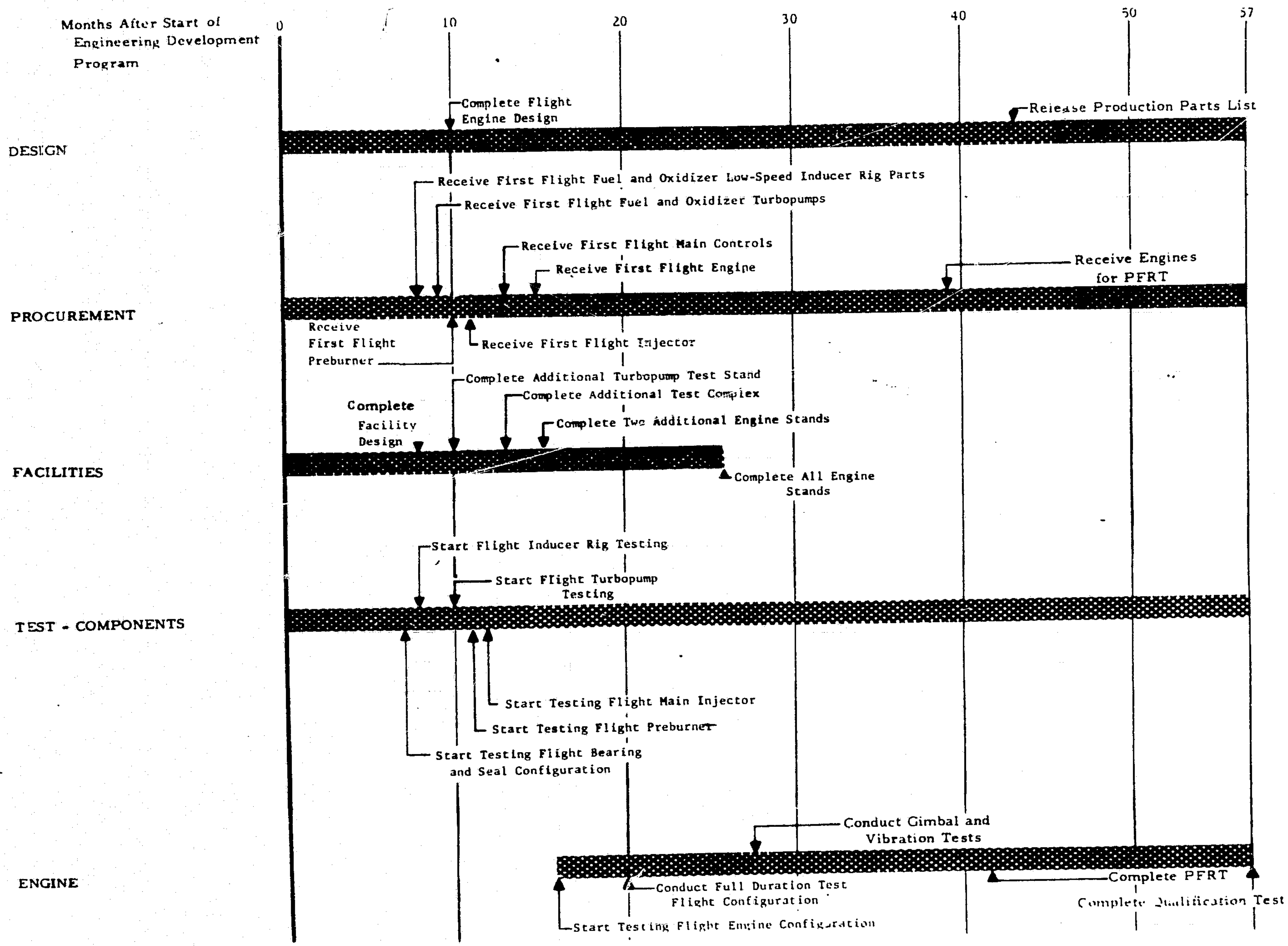


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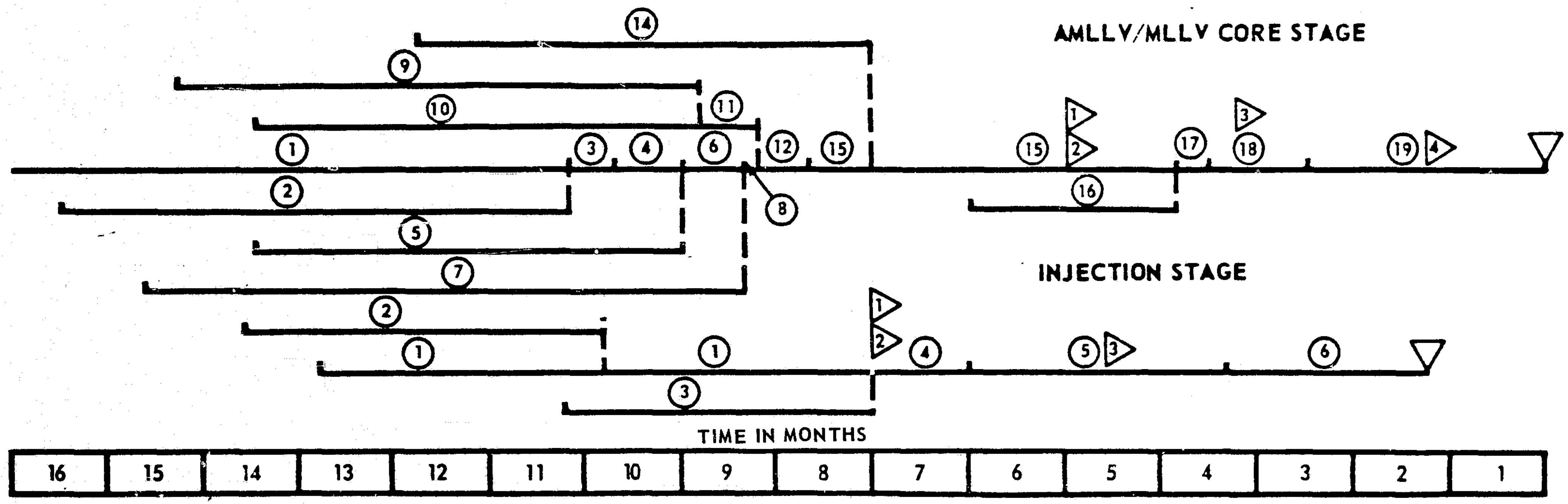
FIGURE 8.2.3.0-1 MULTICHAMBER/PLUG LIQUID ENGINE - OVERALL PROGRAM SCHEDULE



AMLLV/MLLV CORE STAGE

1. COMMON BULKHEAD BUILD-UP
2. UPPER BULKHEAD BUILD-UP
3. JOIN BULKHEADS
4. HYDROSTATIC TEST - LOX TANK
5. UPPER LH_2 TANK CYL. WELD
6. WELD - LOX TANK TO LH_2 CYL.
7. FORWARD SKIRT ASSEMBLY
8. JOIN - FORWARD SKIRT TO UPPER TANK
9. LOWER BULKHEAD BUILD-UP
10. LOWER LH_2 CYLINDER WELD
11. WELD - LWR. BLKHD. TO LWR CYL.
12. WELD - UPPER AND LOWER TANK HALOGS
13. HYDROSTATIC TEST - LH_2 TANK
14. AFT. SKIRT ASSEMBLY
15. FINAL ASSEMBLY
16. CENTER PLUG ASSEMBLY
17. JOIN CENTER PLUG TO AFT SKIRT
18. ENGINE INSTALLATION
19. POST MANUFACTURING CHECK

STATIC TEST VEHICLE

▷1 CONFIGURATION CHANGE AND TEST EQUIPMENT ADDED-SAME FLOW.

D. T. V.

▷2 REDUCTION OF SYSTEMS-DECREASE FLOW OF FINAL ASSY. BY APPROX. ONE-HALF

▷3 ENGINE SIMULATORS REQUIRED-DECREASE FLOW BY ONE-THIRD

▷4 NOT REQUIRED FOR D. T. V.

INJECTION STAGE

1. RINGS AND SKIN PANELS - ASSY. AND WELD
2. LH_2 TANK BUILD-UP
3. LOX TANK BUILD-UP
4. ENGINE INSTALLATION
5. FINAL ASSEMBLY
6. POST MANUFACTURING CHECK

▷1 THREE WAFERS REQUIRE COMMON CONSTRUCTION TO THIS POINT.

▷2 ENGINES INSTALLED ON LOWER "WAFER" ONLY

▷3 STACK "WAFERS" AND INSTALL SYSTEMS

FIGURE 8.3.0.0-1 SEQUENTIAL FLOW TIMELINE FOR STAGE ASSEMBLY

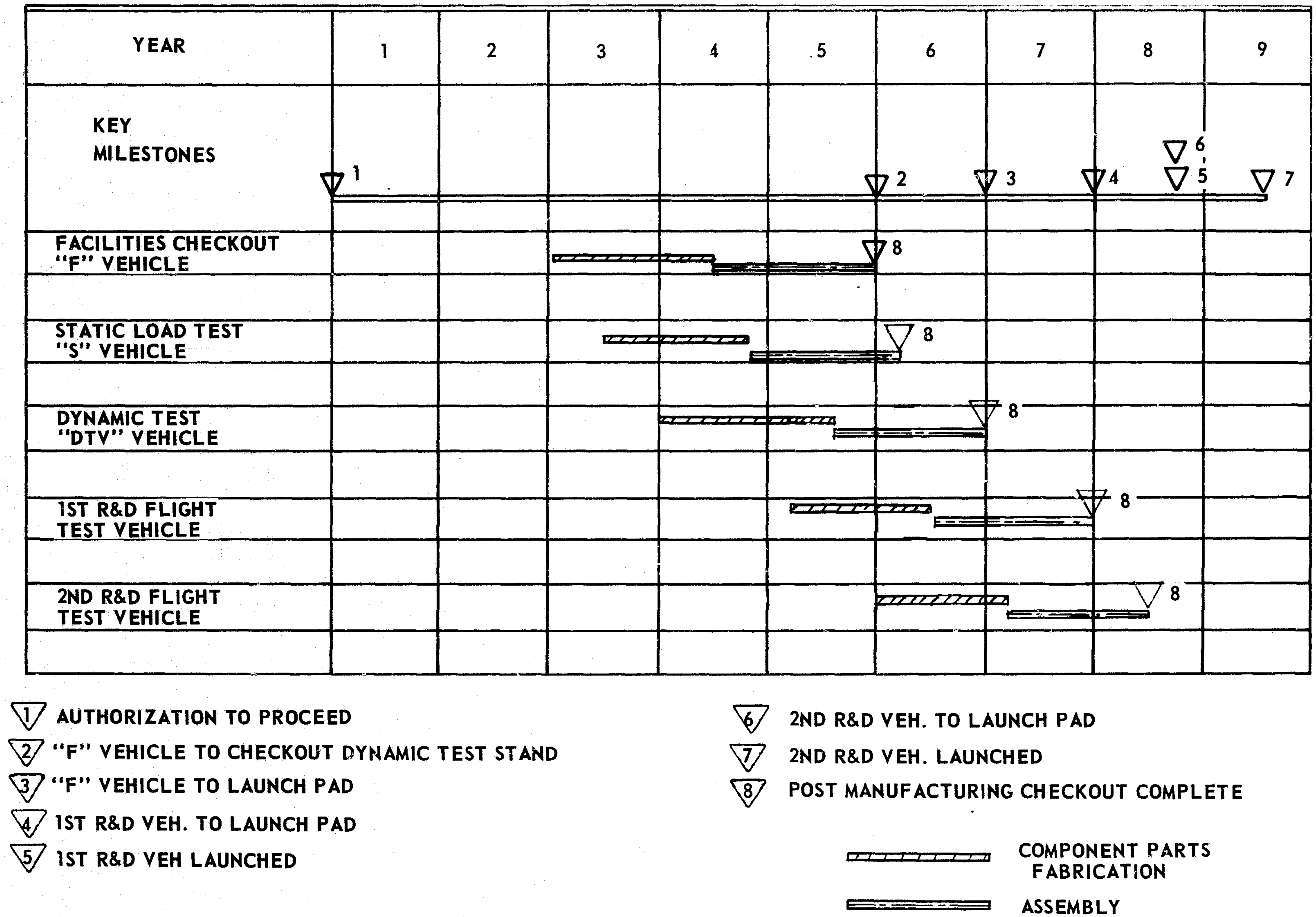
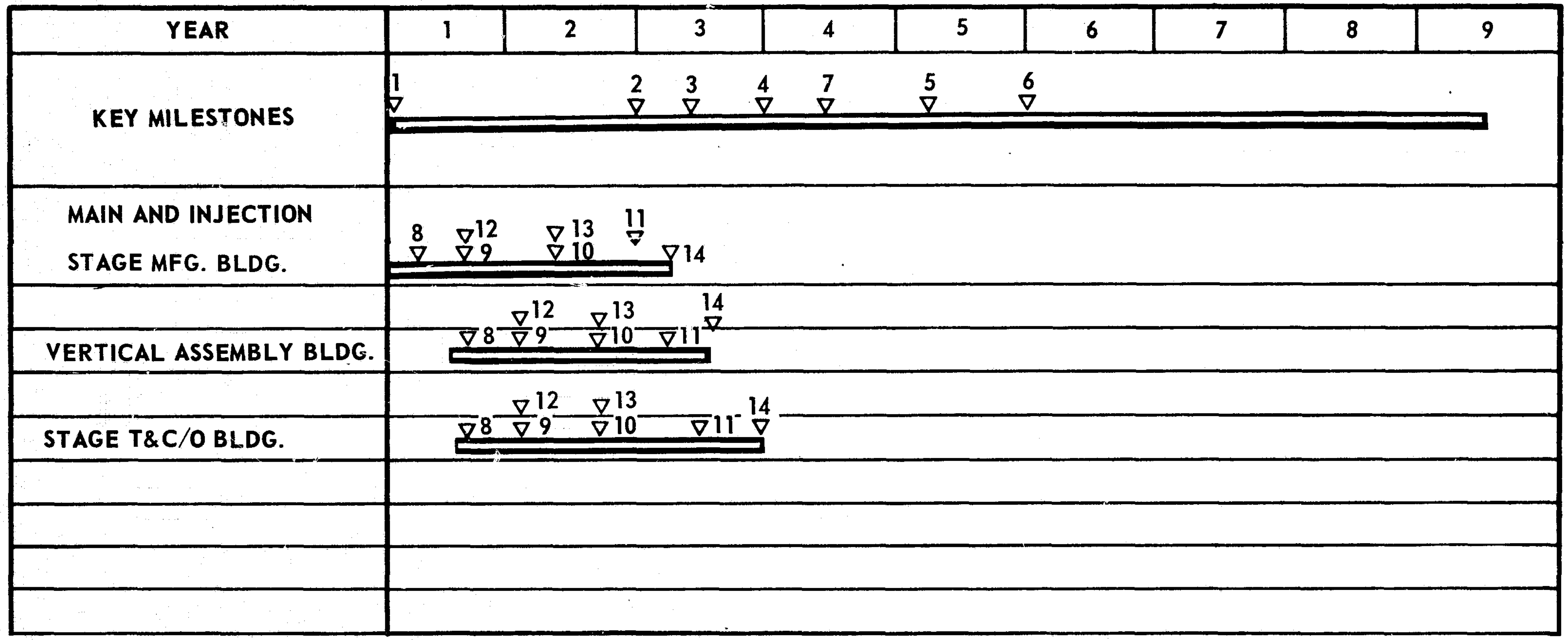


FIGURE 8.3.0.0-2 MAIN AND INJECTION STAGE MANUFACTURING SCHEDULE



▽1 AUTHORIZATION TO PROCEED	▽8 DESIGN CRITERIA COMPLETED
▽2 START FABRICATION OF "F" VEH.	▽9 DESIGN 30% COMPLETED-CONSTRUCTION START
▽3 START FAB. OF "S" VEH.	▽10 DESIGN COMPLETED
▽4 START FAB. OF "DTV"	▽11 CONSTRUCTION COMPLETED
▽5 START FAB. OF 1ST R&D FLIGHT VEH.	▽12 LONG LEAD EQUIPMENT ORDERED
▽6 START FAB. OF 2ND R&D FLIGHT VEH.	▽13 STANDARD EQUIPMENT ORDERED
▽7. START VERTICAL ASSY OF "F" VEH.	▽14 EQUIPMENT INSTALLED AND CHECKED OUT

FIGURE 8.3.0.0-3 MANUFACTURING FACILITY - BRICK AND MORTAR AND EQUIPMENT

8.3 (Continued)

"F" vehicle is less complicated than a flight vehicle) this time was extended to 18 months to allow for checkout of the manufacturing and testing GSE.

The three month overlap between start of fabrication of components and completion of the facility can be justified on the basis that the entire facility does not need to be completed before areas of it can be utilized. Although the stage parts are priced as though they were fabricated in the new facility, the normal practice is to use the stage contractors existing facilities for start of the manufacturing process or to purchase them from vendors, who utilize their existing facilities. With these considerations, it is believed that no significant effects on program plans or costs result from this overlap.

The remaining vehicles of the R&D program are shown as starting on a date that makes the vehicle available as required for testing or launch. Facilities required for manufacture of the main and injection stages have been identified as, (1) a parts and subsystem building, (2) a vertical assembly building, and (3) a stage test and checkout building.

8.4 TRANSPORTATION SCHEDULES

The major transportation requirements for the main and injection stages are as follows:

a. Land transportation of the stages at the factory site,

b. Barge transportation of the stages from the factory to the launch facility.

No schedules have been prepared for these functions. The land transportation is a continuous part of the manufacturing and test operations. The barge transportation is based on a 5 day trip for the main stage barge and a 4 day trip for the injection stage barge. These items are based on the 4 day trip required for the S-IC stage.

Overall program requirements indicate the need for the following major stage transportation articles.

Description	Quantity MLLV	Quantity AMLLV
Main Stage Land Transporter	2	2
Injection Stage Land Transporter	2	2
Land Tow Vehicles	2	2

8.4 (Continued)

Main Stage Barge	1	1
Injection Stage Barge	1	1
SRM Stage Barge	9	13

The schedules shown in Figure 8.4.0.0-1 are for the first unit. Where multiple units are being produced they can either be constructed in parallel or series. In the case of the SRM Stage Barges, it would be mandatory to have multiple production lines.

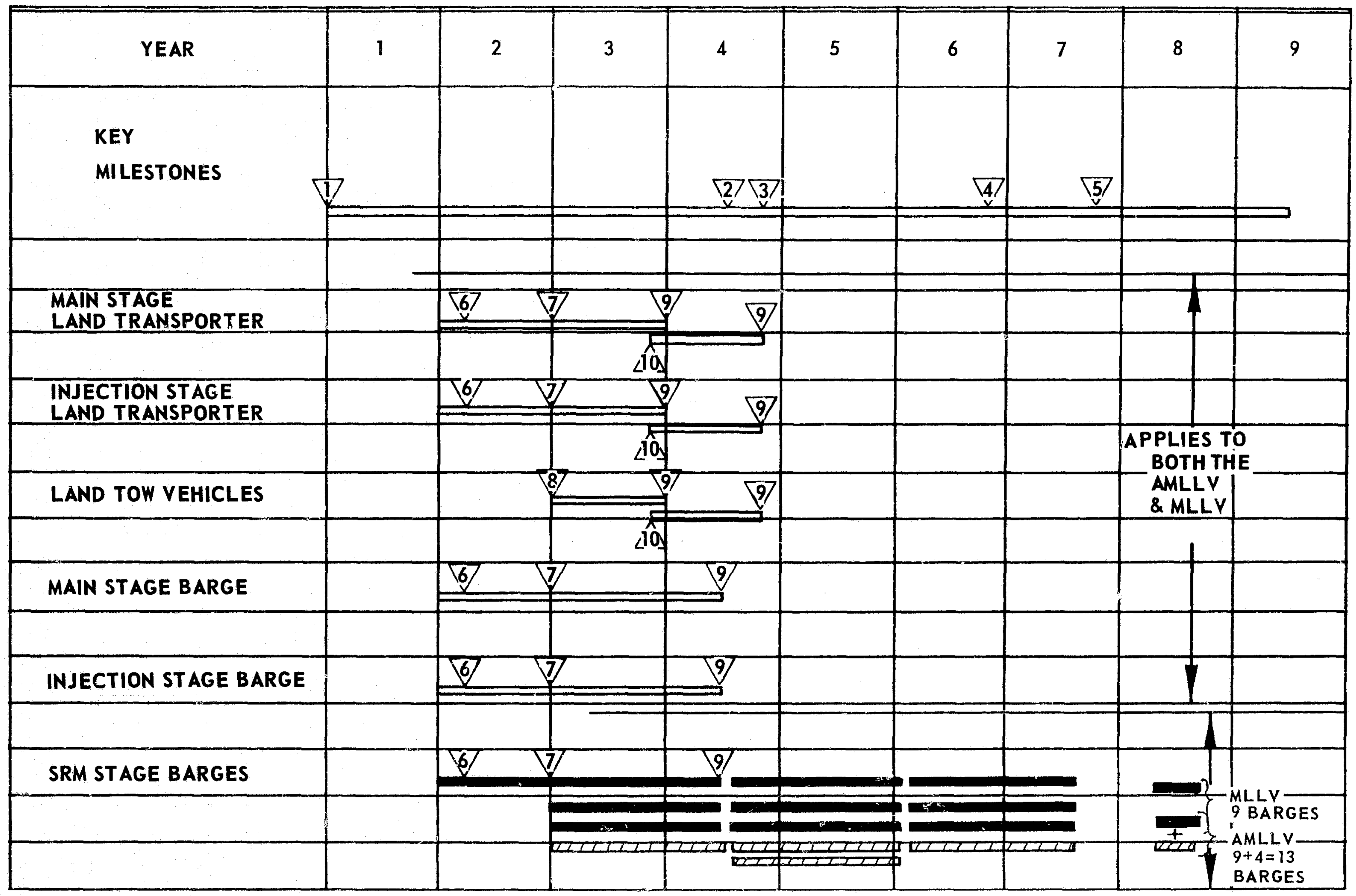
8.5 LAUNCH OPERATIONS SCHEDULE

The operations to be conducted at the launch site include:

1. Receiving inspection
2. Static fire main and injection stages
3. Refurbish main and injection stage
4. Assemble launch vehicle
5. Checkout and Launch
6. Refurbish site after static test firing and launch

Time lines were prepared to cover the entire operations for a complete launch cycle. The timelines were previously shown in Figures 7.3.1.2-1 through -4 in Section 7.3.1.2, AMLLV/MLLV Launch Operation Schedules. These figures show the detail breakdown of the above listed operations.

Facilities schedules for construction and checkout of the launch site were previously shown in Figure 8.2.0.0-1.



1 AUTHORIZATION TO PROCEED
2 1ST SET OF LAND TRANSPORTERS REQUIRED
3 2ND SET OF LAND TRANSPORTERS REQUIRED
4 MAIN AND INJECTION STAGE BARGES REQUIRED
5 ALL BARGES REQUIRED

6 DESIGN CRITERIA COMPLETE
7 DESIGN COMPLETE – START CONSTRUCTION
8 LONG LEAD EQUIPMENT ORDERED
9 EQUIPMENT ON DOCK
10 START CONSTRUCTION 2ND UNIT

FIGURE 8.4.0.0-1 TRANSPORTATION EQUIPMENT FABRICATION

9.0 RESOURCE IMPLICATIONS OF PROGRAM OPTIONS

The resources for the AMLLV and MLLV were defined for vehicle configurations consisting of (1) the main stage with a multichamber/plug propulsion system, (2) an injection stage consisting of an engine module with one or two fuel modules, and (3) 260 inch SRM strap-on stages.

There are other program options which will have a significant impact on the resources as well as the program costs. These options include:

a. The toroidal/aerospike propulsion system in lieu of the multichamber/plug propulsion system on the main stage.

b. The 260 inch SRM strap-on stages versus 260 inch liquid strap-on stages.

c. The 260 inch SRM strap-on stages versus the 156 inch SRM strap-on stages.

The resource data for the multichamber/plug propulsion system is shown in paragraph 4.2.8. This data was supplied by the Pratt and Whitney Division of United Aircraft Corporation. Resource data for the toroidal/aerospike is shown in Section 9.1. This data was supplied by the Rocketdyne Division of the North American Rockwell Corporation.

The resource implication data for the 260 inch SRM stage was supplied by the Aerojet General Corporation and is shown in paragraph 4.2.9. The resource data for the 260 inch liquid engine propulsion strap-on stage was obtained from a prior study program "Studies of Improved Saturn V Vehicles" Vehicle Description, MLV-SAT-V-23(L) (Reference 9.0.0.0-1). This data has been extrapolated from the referenced document and is shown in Section 9.2.

The resources for the 156 inch SRM stage was extrapolated from Reference 9.0.0.0-1, Vehicle Description, MLV-SAT-V-25(S) shown in Section 9.3.

9.1 TOROIDAL/AEROSPIKE ENGINE PROGRAM PLAN

Module development program plans for large booster toroidal/aerospike engines have been formulated based on past history of booster engine development, hardware lead times, and test requirements peculiar to these new engine configurations. Total program cost comparisons, including engineering, fabrication, and test

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9.0.0.0-1 Studies of Improved Saturn V Vehicles, NASA Contract NAS8-20266, Document D5-13183-3 and D5-13183-5 dated October 7, 1966.

9.1 (Continued)

costs were prepared for an eight million pound thrust toroidal/aerospike engine using liquid oxygen/liquid hydrogen fuel. Two alternative configurations are proposed. One configuration will utilize 28 modules (6 segments/module) each of which will be powered by a J-2S engine turbomachinery unit delivering 286K pounds thrust. The second configuration will utilize 8 modules (20 segments/module) each of which will be powered by an advanced turbomachinery unit delivering one million pounds of thrust. Either configuration will deliver a total of eight million pounds of thrust.

Historically, development of liquid rocket engines has been accomplished with a large number of complete engine system tests. Component and subsystem testing was utilized primarily to ensure the suitability of a component for engine system tests and to supplement the engine test program where required. The toroidal/aerospike engine, because of its unique design, will allow a new approach to the development of liquid rocket engines.

The toroidal/aerospike engine will consist of a number of independent "building block" modules. Each module will contain a complete segmented combustor and nozzle assembly with integral turbomachinery, feed system components and system controls. System tests in the development program will be accomplished by testing the basic module.

Complete propulsion system tests, i.e., all modules assembled, would only be conducted as part of the stage static firing test program. (This is similar to the approach used in the engine cluster tests for the S-1B, S-1C, and S-II stage systems.) Figures 9.1.0.0-1 and 9.1.0.0-2 will provide identification of segment-module-engine relationships associated with the development of an eight million pound thrust toroidal/aerospike engine having 28 or 8 modules, respectively.

9.1.1 Toroidal/Aerospike Engine Development, Test Requirements and Program Schedules

The toroidal/aerospike thrust chamber development will be accomplished initially with full scale, single combustor segment tests, followed by testing of multiple segments which include the nozzle portion of the chamber. This thrust chamber development approach will minimize the testing costs and will achieve a high test frequency and long test durations early in the program. As a consequence, a rapid and efficient thrust chamber reliability growth will be achieved and a highly reliable thrust chamber will be available before module tests begin. The existence of the high reliability in the thrust chamber will permit module testing to be performed to investigate system interaction effects, rather than to expose thrust chamber failure modes; with the end result being that module (system) tests can be minimized in development of a toroidal/aerospike engine.

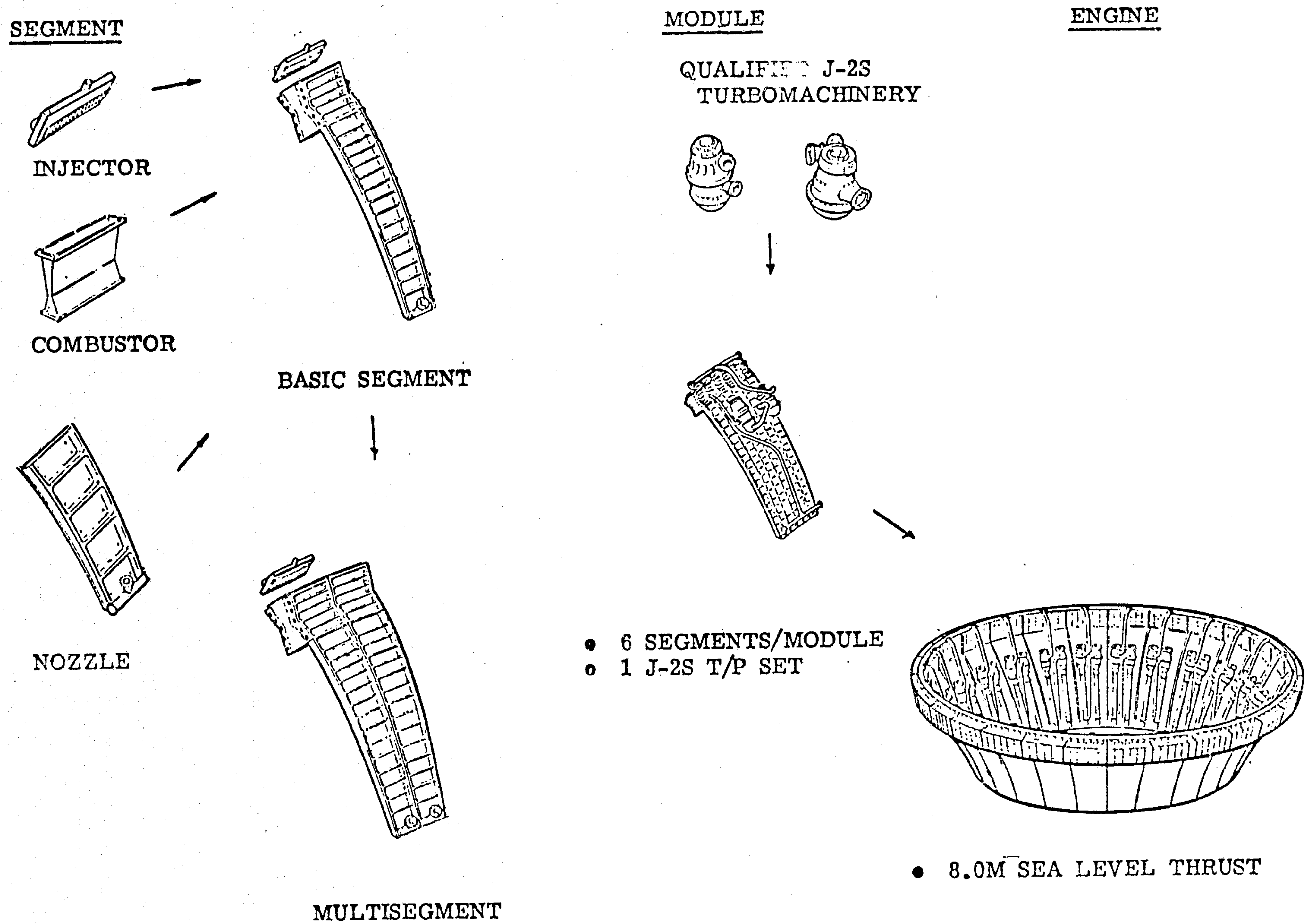


FIGURE 9.1.0.0-1 TOROIDAL/AEROSPIKE ENGINE DEVELOPMENT
(28 MODULE CONFIGURATION)

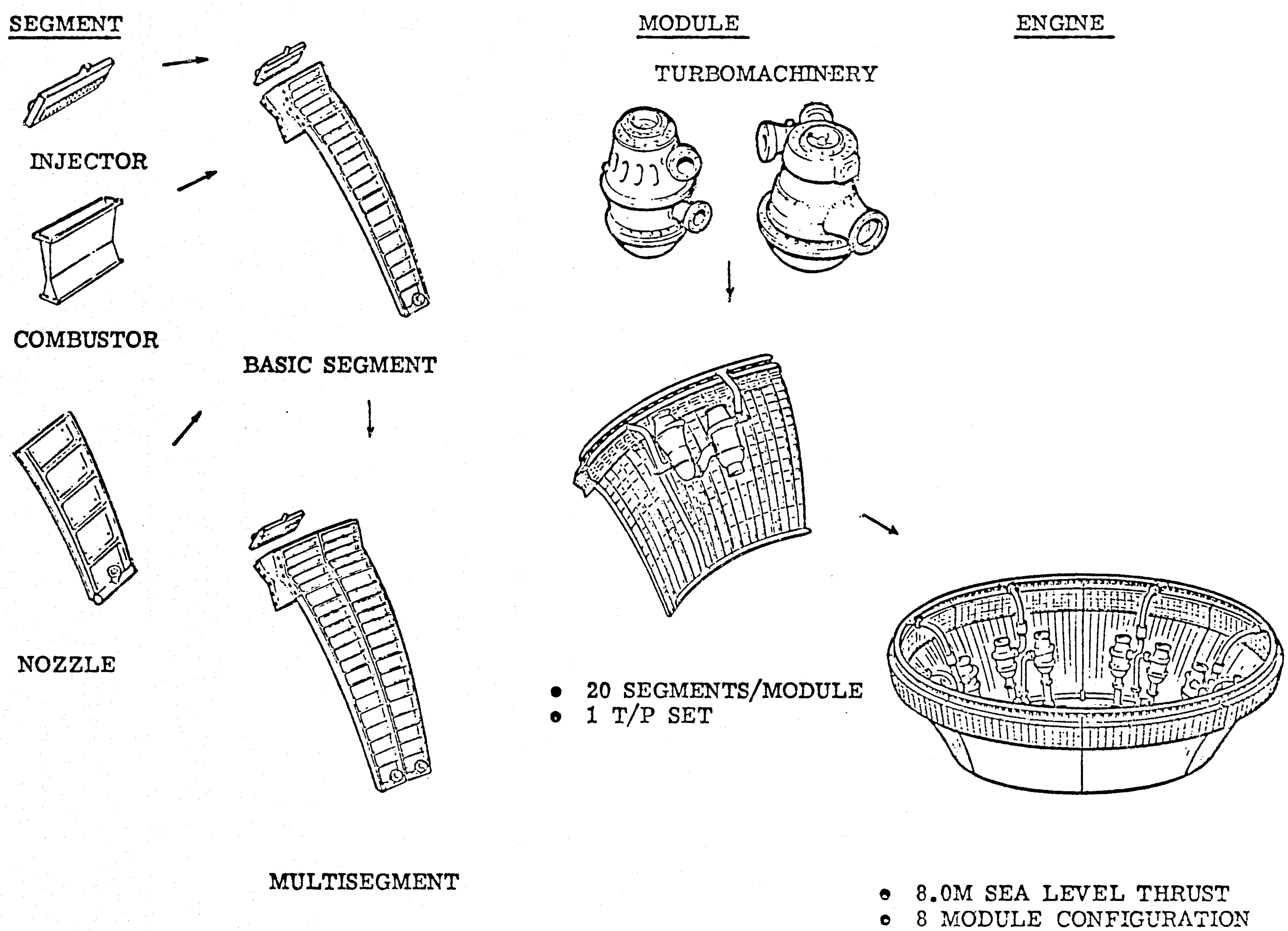


FIGURE 9.1.0.0-2 TOROIDAL/AEROSPIKE ENGINE DEVELOPMENT (8 MODULE CONFIGURATION)

9.1.1 (Continued)

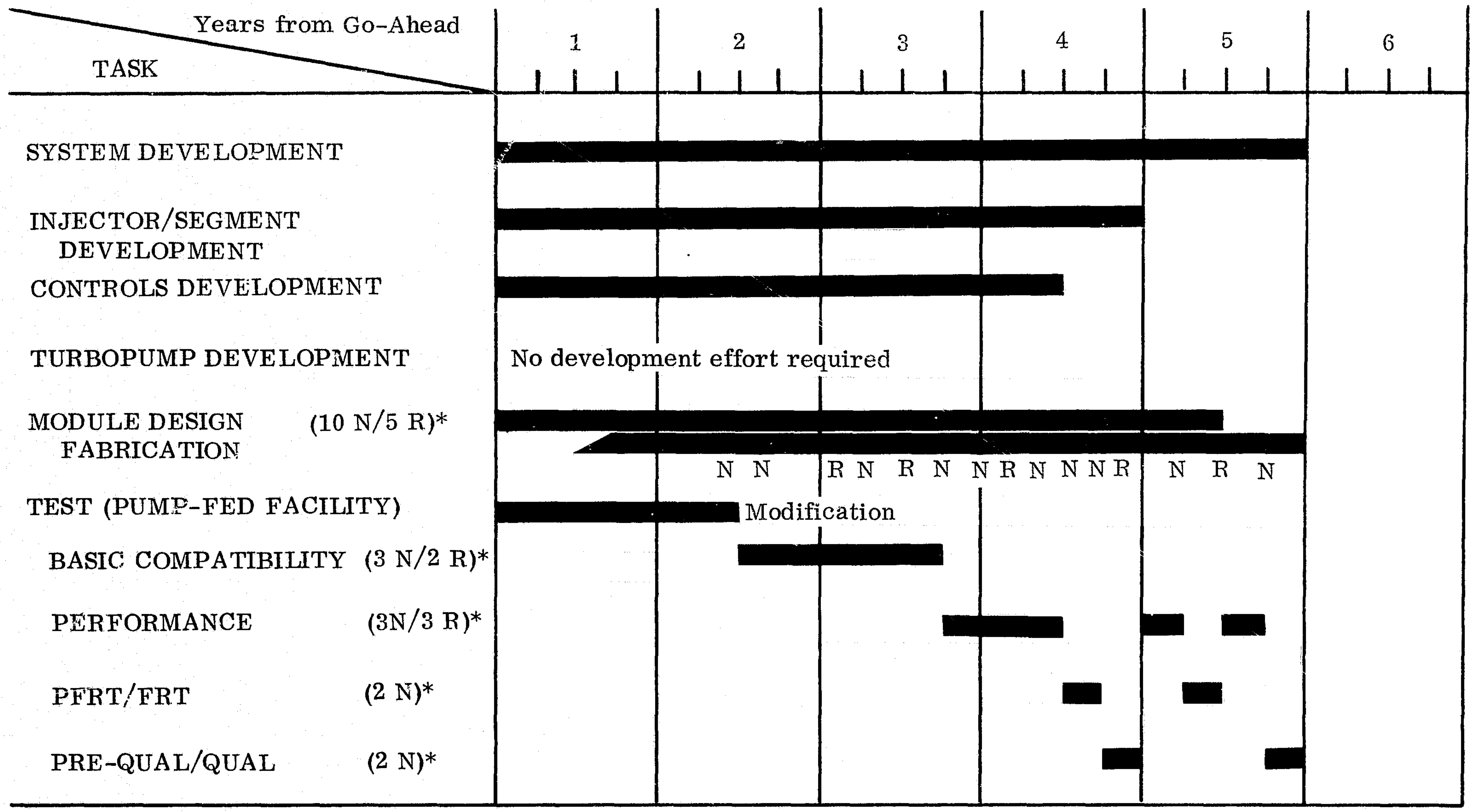
Development schedules for the qualification of the 286,000 pounds thrust module and the 1,000,000 pounds thrust module configurations are provided as Figures 9.1.1.0-1 and 9.1.1.0-2, respectively. As noted in these figures, six major tasks have been defined for each development plan. They are as follows: System Development, Injector/Segment Development, Controls Development, Turbopump Development, Module Design/Fabrication, and Module Testing. Predicted durations for the development of a module, through Qualification testing, are five and six years for the 286K pounds thrust module/engine and 1M pounds thrust module configurations, respectively. These development programs are based on the assumption that current technology effort will be continued through demonstration of module feasibility.

The System Development task will occur over the duration of each program. It will be basically an all encompassing category which will include engineering manpower from the Project Office, Program Office, Structures, Reliability, Materials and Processes, Performance Analysis, Component Maintenance Support, etc.

A detailed development program schedule has been defined for the cast Injector and Segment which will be identical for each module program. The Injector/Segment development program plan is predicated on the assumption that the casting technology has been previously demonstrated on similar configuration hardware, i.e., material selection, casting parameters, casting technique, compatibility, etc., and will not require extensive development effort other than for the specific application. The major effort will be directed toward injector development and resultant high performance. Component testing will be conducted concurrently with module testing. The Injector/Segment development program will include the accomplishment of the following test tasks:

- Injector performance
- Injector stability
- Segment integrity
- Segment performance
- Segment/injector limits
- Multi-segment integrity
- Liquid injection thrust vector control (LITVC) performance
- Module test support

Fabrication and development of the 286K module configuration (6 segments/module) is based upon using qualified J-2S turbomachinery, controls, and applicable feed system hardware. Turbopump testing would, therefore, not be required. The one million pound thrust (1M) module engine configuration (20 segments/module) will require the development of a new advanced turbomachinery unit, valves, and associated running gear.



Hardware Requirements:

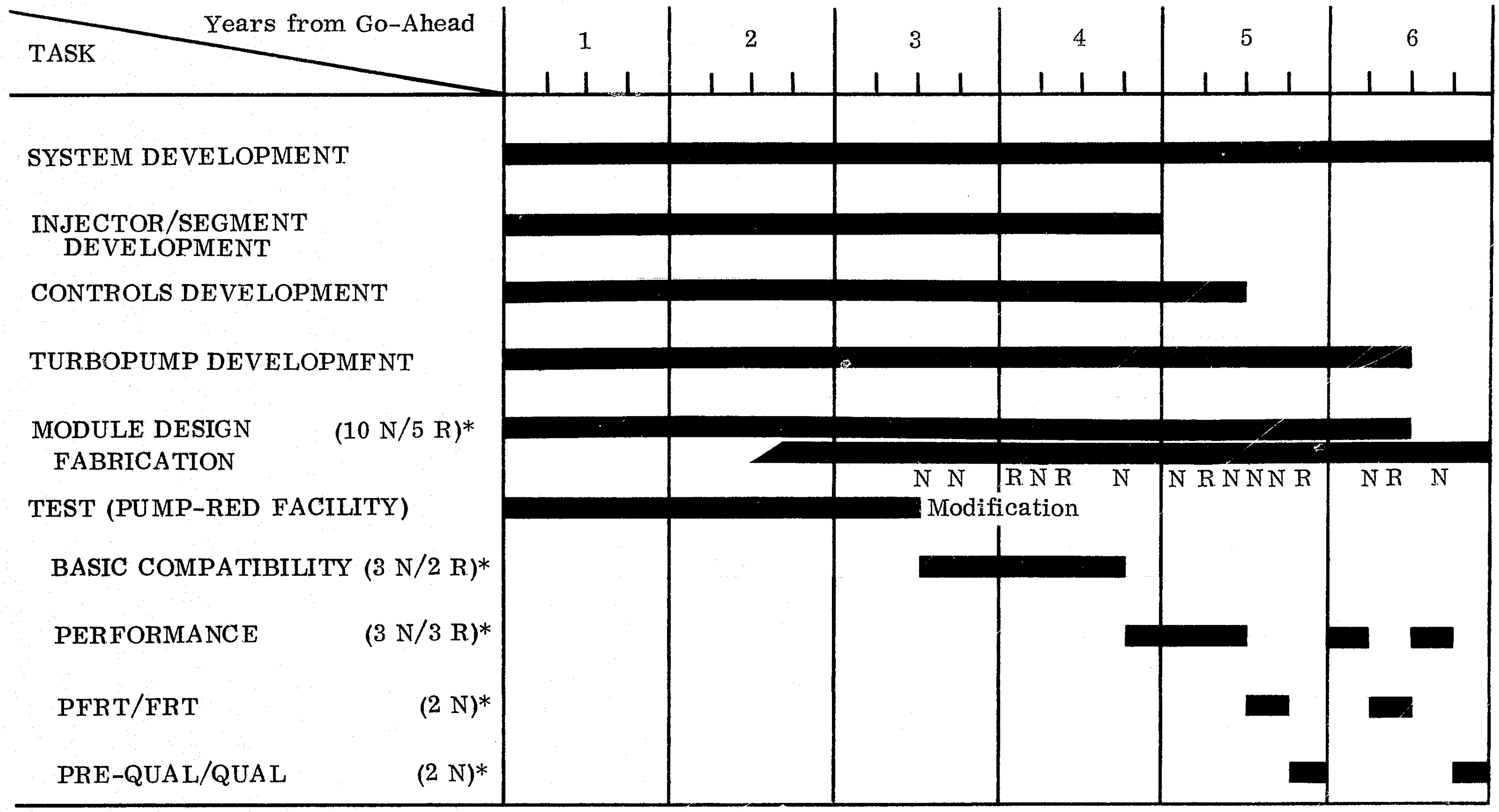
70 Segment Assemblies
12 Turbopump Assemblies
12 Feed Systems/Running Gear
3 SITVC Systems

* N = New R = Rebuilt

Assumptions:

1) 28 Modules/Engine
2) 6 Segment Assemblies/Module
3) Use J-2S Qual Turbopump Assembly
4) Use J-2S Valves/Running Gear
5) Previous Pump-Fed Module Testing completed on similar configuration hardware

FIGURE 9.1.1.0-1 286K MODULE DEVELOPMENT PROGRAM 6 SEGMENTS/MODULE



Hardware Requirements:
230 Segment Assemblies
10 Turbopump Assemblies (Reuse Component Pumps)
12 Feed Systems/Running Gear
3 SITVC Systems

* N = New R = Rebuilt

Assumptions:
1) 8 Modules/Engine
2) 20 Segment/Assemblies/Module
3) Develop New Turbopump Assembly
4) Develop New Valves/Running Gear
5) Previous Pump-Fed Module Testing completed on similar segment configurations

FIGURE 9.1.1.0-2 1M MODULE DEVELOPMENT PROGRAM 20 SEGMENTS/MODULE

9.1.1 (Continued)

Development of an LO_2/LH_2 turbopump system will be a major task within the frame-work of the 1M thrust module assembly program. Turbomachinery testing will commence 18 months after contract go-ahead. Completion of duration demonstration tests within two years will allow for design release and fabrication of the first module assembly 30 months after go-ahead. Final turbopump development testing will be concurrent with module testing, as noted on the development schedule (Figure 9.1.1.0-2).

Module design effort for either program would be initiated at contract go-ahead. Design release of the segment assemblies for the initial module assemblies will be based upon first design of the segment, and will not be dependent upon component hot fire results. This will be possible because segment technology and hot fire integrity will have been demonstrated prior to this program.

Fabrication of the first 286K module will be scheduled for completion 18 months after go-ahead; however, fabrication of the first 1M module will not be scheduled for completion until 30 months after go-ahead, as noted above. Development of the turbomachinery and controls will be the pacing item for the 1M module assembly.

9.1.2 Toroidal/Aerospike Engine Resource Requirements

The number of units to be fabricated and subsequently tested (combination of new builds and rebuilds) will be based upon hardware requirements experienced on past Rocketdyne engine system development programs, and the requirements peculiar to this new engine concept. The requirement of two modules for Pre-Flight Rating Test/Flight Rating Test (PFRT/FRT) and two modules for Qualification (QUAL) is consistent with previous programs. The module test program objectives will be divided into four groups (see Figures 9.1.1.0-1 and -2). Initially, basic compatibility will be demonstrated which will include controls, feed system, sequence, stability, tapoff, dynamics, structural integrity, thrust mount and assembly verification testing. The next group of tests will provide evaluation of module performance, throttling limits, mixture ratio excursions, base pressure, secondary injection thrust vector control and limits of operation. Coordinated with performance testing will be both PFRT/FRT and pre-QUAL demonstrations. The final series of tests to be defined in this program will be the module qualification.

The Preliminary Flight Rating Test (PFRT) program will be conducted to demonstrate the suitability of a module for use in static testing. Toroidal/aerospike modules to be used in this test series will be deliverable modules which will have previously demonstrated acceptance capability (static leakage, electrical and mechanical, calibration, basic compatibility, and inspection tests). PFRT tests will include module performance, leakage and structural integrity tests. The Flight Rating

9.1.2 (Continued)

Test (FRT) program will be conducted to demonstrate the suitability of a module for flight operations at nominal design parameter values. The FRT tests will include module performance, start-stop, leakage, and assembly integrity tests. The combined PFRT/FRT module test program is expected to use two modules and will perform 40 tests accumulating 6,000 second duration.

The Qualification Test Program (QUAL) will be conducted to demonstrate the suitability of a module for production and flight. The test series will include duration performance tests (with throttling and mixture ratio excursion tests), thrust vector control tests, safety limits (operability range), and reliability demonstration tests. A total of two modules shall be used to complete the Pre-QUAL/QUAL program and 40 tests will be conducted accumulating 6,000 seconds duration.

The number of tests to be stipulated within the various program alternatives will be based upon efficient facility utilization and fabrication schedules, and will be designed to achieve 99 percent reliability with a minimum of 90 percent confidence level per module.

Facility utilization (single pump-fed position) will be based upon nine and seven tests/month for the 286K and 1M modules, respectively. Fabrication scheduling will be based on a minimum of twelve weeks per module delivery.

A pricing analysis was conducted for these two development programs by Rocketdyne. The design and development costs for the 286K module and the 1M module are presented in Table 9.1.2.0-I and -II, respectively. Table 9.1.2.0-III is a cost summary for 1M and 2M module applications to the AMLLV listing development and production costs. Table 9.1.2.0-IV is a cost summary for the 286K and 1M modules for the MLLV.

TABLE 9.1.2.0-I TOROIDAL/AEROSPIKE ENGINE (286K MODULE) DESIGN AND DEVELOPMENT COSTS

	"A"	"B" Development Test				
	Get Ready	Component	Engine	PFRT	Qual.	Total
Engineering	$5.7	$5.8	$9.0	$2.0	$2.0	$24.5
Test		2.8	3.3	.5	.5	7.1
Equipment	.2	.5	1.5			2.2
Tooling (Basic)	2.0	.5	1.0			3.5
Fabrication		2.8	11.1	3.2	3.2	20.3
Subtotal	$7.9	$12.4	$25.9	$5.7	$5.7	$57.6
Total (Including Fee)						$64.0

Production	"C" (First Unit)	(100th Unit)
Engineering	$.06	$.04
Test	.08	.05
Tooling (Maintenance)	.09	.05
Fabrication	1.01	.61
Subtotal	$1.24	$.75
Total (Including Fee)	$1.40	$.80
Production	**(Non-Recurring)**	
Tooling (Basic)	$5.0	
Equipment	1.5	
GSE	2.5	
Subtotal	$9.0	
Total (Including Fee)	$10.0	

NOTE: 1968 Dollars in Millions

TABLE 9.1.2.0-II TOROIDAL/AEROSPIKE ENGINE (1M MODULE) DESIGN AND DEVELOPMENT COSTS

	"A"	"B" Development Test				
	Get Ready	Component	Engine	PFRT	Qual.	Total
Engineering	$7.5	$11.0	$14.3	$2.5	$2.5	$37.8
Test		5.3	3.6	.6	.6	10.1
Equipment	.5	4.8	10.8			16.1
Tooling (Basic)	3.0	2.0	1.0			6.0
Fabrication		15.1	24.0	6.4	6.4	51.9
Subtotal	$11.0	$38.2	$53.7	$9.4	$9.4	$121.9
Total (Including Fee)						$134.0

Production	"C" (First Unit)	(30th Unit)
Engineering	$.14	$.09
Test	.17	.11
Tooling (Maintenance)	.24	.16
Fabrication	2.36	1.59
Subtotal	$2.91	$1.95
Total (Including Fee)	$3.20	$2.10
Production	**(Non-Recurring)**	
Tooling (Basic)	$4.0	
Equipment	2.5	
GSE	4.0	
Subtotal	$10.5	
Total (Including Fee)	$11.6	

NOTE: 1968 Dollars in Millions

TABLE 9.1.2.0-III AMLLV - TOROIDAL/AEROSPIKE ENGINE COST

CHAMBER PRESSURE		2000 PSI	2000 PSI
MODULE THRUST (LBS)		1000 K	2000 K
CATEGORY	COST ITEM	DOLLARS IN MILLIONS	
	DESIGN & DEVELOPMENT		
"A" Get Ready Costs + "B" Development Test Costs	Engineering	$ 43.2	$ 50.5
	Test	11.2	13.0
	Equipment	16.4	21.1
	Tooling (Basic)	7.0	10.0
	Fabrication	55.0	89.9
	Subtotal	$132.8	$184.5
	PRODUCTION		
	Tooling (Basic)	$ 4.0	$ 6.0
	Equipment	3.0	3.5
	GSE	4.5	6.0
	Subtotal	$ 11.5	$ 15.5
Total Non-Recurring		$144.3*	$200.0*
	PRODUCTION	First Unit	First Unit
	Engineering	$ .15	$ .25
	Test	.18	.30
	Tooling (Maintenance)	.26	.42
	Fabrication	2.51	4.09
"C" First Unit Cost	Total	$ 3.10	$ 5.06
		60th Unit	30th Unit
	Engineering	$ .09	$ .17
	Test	.11	.21
	Tooling (Maintenance)	.17	.30
	Fabrication	1.55	2.75
	Total	$ 1.92	$ 3.43

*Propellants for the R&D Test Program were Assumed to be Government Furnished

TABLE 9.1.2.0-IV MLLV - TOROIDAL/AEROSPIKE ENGINE COST SUMMARY

CHAMBER PRESSURE		1200 PSI		2000 PSI
MODULE THRUST (LBS)		286K*	1000K	1000K
CATEGROY	COST ITEM	DOLLARS IN MILLIONS		
"A" Get Ready Costs	Engineering	$ 5.7	$ 7.5	Included in "B"
	Equipment	.2	.5	
	Tooling (Basic)	2.0	3.0	
	Subtotal	$ 7.9	$ 11.0	
	PRODUCTION			
	Tooling (Basic)	$ 5.0	$ 4.0	$ 4.0
	Equipment	1.5	2.5	3.0
	GSE	2.5	4.0	4.5
	Subtotal	$ 9.0	$ 10.5	$ 11.5
	Total	$16.9	$ 21.5	$ 11.5
"B" Development Test Costs	Engineering	$24.5	$ 37.8	$ 43.2
	Test	7.1	10.1	11.2
	Equipment	2.2	16.1	16.4
	Tooling (Basic)	3.5	6.0	7.0
	Fabrication	20.3	51.9	58.0
	Subtotal	$57.6	$121.9	$135.8
Total Non-Recurring		$74.5**	$143.4**	$147.3**
"C" First Unit Costs	PRODUCTION	First Unit	First Unit	First Unit
	Engineering	$ .06	$ .14	$ .15
	Test	.08	.17	.18
	Tooling (Maintenance)	.09	.24	.27
	Fabrication	1.01	2.36	2.64
	Total	$ 1.24	$ 2.91	$ 3.24
		100th Unit	30th Unit	30th Unit
	Engineering	$ .04	$ .09	$ .10
	Test	.05	.11	.12
	Tooling (Maintenance)	.05	.16	.18
	Fabrication	.61	1.59	1.78
	Total	$ .75	$ 1.95	$ 2.18

Notes:

*Uses J-2S Turbo-Machinery
**Propellants for R&D Test Programs were Assumed to be Government Furnished

9.2 LIQUID PROPELLANT STRAP-ON STAGES

The liquid propellant strap-on stages are an alternative for the solid rocket motor (SRM) stages. The liquid propellant strap-on stages for this comparison were 260 inches in diameter with N_2O_4 and UDMH fuel. For the purpose of this discussion, it was assumed that the delivered cost at the manufacturing loading dock would be the same for the SRM stage and the liquid propellant stage (i.e. costs would be the same for development, test and manufacturing). The cost of the fuel for the liquid strap-on stage was assumed to be included in the above liquid propellant stage costs.

The comparison of the AMLLV liquid strap-on stage to the AMLLV SRM stage was, therefore, based on post manufacturing operations (i.e. handling, transportation and launch) and associated equipment and facility requirements. The SRM stage is described from development through manufacture and usage in paragraph 4.2.9 - SRM Development Tests, paragraph 4.2.10 - Flight Tests, Section 5.4 - SRM Manufacturing Plan and Section 7.0 - Launch Plan. This section (9.2) will be limited to a brief discussion of the major facets involved in processing the liquid strap-on stages, in order to provide a basis for comparison.

Table 9.2.0.0-I outlines the processing of the AMLLV SRM stage and the AMLLV liquid stage from the manufacturing site to the launch facility and through launch. Costs for most of the operations are similar for the two stages, and are not listed. Where substantial differences exist, either in "get ready" non-recurring costs, or operating and maintenance recurring costs, these costs are noted. Table 9.2.0.0-I compares post-manufacturing processing of the two strap-on configurations. Differences in costs are listed in the center "delta" column, with itallics enclosing the liquid strap-on delta costs.

Basic assumptions used for this comparison were:

a. The liquid strap-on stage would be in the "low cost booster" category, economical and expendable, using the same fuel as the main stage.

b. The liquid strap-ons would be dimensionally configured so that the number of strap-ons used would achieve the same orbit for the payload as an equal number of SRM stages.

c. The liquid strap-on stages and the SRM stages would be static fired only during developmental testing. When R&D development testing is concluded, either type of strap-ons would be manufactured, assembled and thoroughly tested (less static firing) at the manufacturing complex. They will then be loaded on barges at the manufacturing site and shipped directly to the launch complex, needing only a receiving inspection before vehicle stacking.

TABLE 9.2.0.0-I SRM STAGE AND LIQUID PROPELLANT STRAP-ON STAGE POST-MFG. TO LAUNCH PROCESSING CHART

SOLID ROCKET MOTOR (SRM) STAGE PROCESSING ACTIVITIES	SRM STAGE COST	DELTA SRM (LIQ. STG.)	LIQUID STAGE COST	LIQUID PROPELLANT STAGE PROCESSING ACTIVITIES
1. Load On Barge at Manufacturing Facility	Fueled SRM Cost	Same	Strap-On Stage & Fuel Cost	1. Load on Barge at Manufacturing Facility
2. Transport to KSC SRM Stage Receiving Area	$221,000	$95,000	$126,000	2. Transport to KSC Launch Facility
3. Perform Receiving Inspection on Barge				3. Unload Stage Onto Pad W/Crane Hoist
4. Store on Barge Until Required on Liquid Stage				4. Transfer to Shop Area & Conduct Receiving Inspection
5. Unload SRM from Barge Onto Pad W/Roll Ramp Actuators				5. Store in Pad Storage Area
6. Move by Gantry Crane to Rotation Slip & Rotate				6. Move to Silo and Insert for Vehicle Stacking
7. Move to Silo and Insert				7. Align Stage and Attach to Main Stage
8. Align SRM Stage and Attach to Core Stage				8. Vehicle Integration, Test and Checkout
9. Vehicle Integration, Test and Checkout				9. CDDT - Fueling and Defueling Operations
10. CDDT				10. Prepare for Launch - Countdown Sequence
11. Prepare for Launch - Countdown Sequence				11. Launch
12. Launch				
DELTA TOTAL FOR RECURRING COSTS		$95,000		
NON-RECURRING "GET READY" COSTS				NON-RECURRING "GET READY" COSTS
1. Barges - 13 required	$26,762,000	$21,426,000	$5,184,000	1. Barges - 2 required
		(3,696,000)	3,696,000	2. Transporters - 16 required
		(246,000)	246,000	3. Tow Vehicles - 3 required
2. Gantry Crane for SRM Loads	26,610,000	10,610,000	12,000,000	4. Gantry Crane W/O SRM Loads
3. Propellant Storage & Distribution		(17,000,000)	17,000,000	5. Propellant Storage, etc. Increased for Liquid Stages
DELTA TOTAL FOR NON-RECURRING COSTS		$11,242,000		

9.2 (Continued)

d. The SRM stages will be stored at the launch complex on the barges, removed from centers of activity. The liquid propellant stages will be unloaded upon arrival onto the launch pad, and stored in subterranean rooms within the launch pad structure. No additional storage facilities will be required.

e. The prime assumption is that costs of the two stages, upon reaching the manufacturing facility dock site, are equal. This includes the cost of the liquid fuel for the liquid stages. Major differences occurring in processing after this established base line are noted as delta costs.

Weights will be a factor in transportation and handling costs. The 260 inch SRM stage for the full size AMLLV will weigh approximately 4,200,000 pounds, while the dry weight of a comparable liquid stage will be approximately 172,000 pounds. Storage requirements at the launch site will also affect transportation and handling costs. The great weight and safety requirements of the SRM stages dictate that they will remain on the barge, moored in a protected location until needed for launch.

The SRM stages will be loaded directly from the casting pit onto barges. The barges will be equipped with a cradle for positioning the stage and to distribute the loads. The SRM stages will be removed directly from the barges by the overhead gantry at the launch pad as required for vehicle assembly. The liquid strap-on stages will, however, be wheeled onto the barges on their individual transporters, which will accompany the stages to the launch site. At the launch site, the liquid stages and their transporters will be off loaded and stored until required.

Sixteen new transporters will be required to support a production rate of 24 strap-on stages per year. Their design will be similar to the S-IC transporter. Each transporter will be comprised of separate forward and rear dollies. Each dolly will be equipped with independently suspended, steerable, dual wheel units. It may be possible to use the same dolly units as S-IC on a new frame structure.

New sea-going barges will be required to transfer liquid strap-on stages from Michoud to KSC. The barges can be very similar to the S-IC sea-going barge.

Recurring processing costs for the two configurations differ very little, and are more or less compensating. The exception is the requirement to store the SRM stages on the barges until all the stages have been received, and the vehicle is scheduled for launch. This will necessitate one barge for each SRM stage, plus one spare. Only two liquid strap-on stage barges will be required, as liquid stages will be off loaded immediately upon arrival at the launch facility. The two barges can each make two round trips per month, if required. The SRM barge operating and maintenance costs for each launch cycle of six months will exceed the liquid stage barge operating and maintenance costs by $95,000. Also,

9.2 (Continued)

the initial costs of the 13 SRM stage barges will be $21,426,000 more than the cost of the two liquid stage barges.

It will take more in time and equipment to lift the massive loads of the SRM stages. This difference is partially compensated for by the fact that the SRM stage will undergo only one handling sequence after barge off-loading and will be placed directly in the silo for mating to the main stage. The liquid strap-on stages will first go to the receiving area on the pad, and then will be placed in a subterranean storage room on the pad until needed for stacking the vehicle. While the operating costs of handling the SRM's and the liquid stage on the launch pad will be approximately the same, there will be a $10,610,000 additional cost for the larger gantry required to lift and transport the SRM stages.

Propellant storage and distribution capacities must be increased at the launch facility, if liquid propellant stages are to be used. The cost of additional fuel storage barges, pumping and distribution facilities is estimated at $17,000,000.

There are other differences, but they are considered minor, and should be largely compensating. For implementation in the "near term," it is felt that the current state-of-the-art of the SRM stages (relative to the current state-of-the-art of the low cost liquid stages) justifies the slightly higher "get ready" and operational costs. As the low cost liquid technology increases, it may be desirable to modify the design concept to specify low cost liquid stages in lieu of SRM stages.

9.3 156 INCH SOLID ROCKET MOTOR (SRM) STAGES

The 156 inch SRM stage has certain characteristics which make it a reasonable alternative to the 260 inch SRM stage. For example, the 156 inch motor can be manufactured in segments which can be transported by railroad. Above a 156 inch diameter, the only method of transportation is by barge. The 156 inch SRM stage, therefore, can be transported by two different methods. As a result of the different transportation concepts, different handling,transportation and launch operation options are available to the 156 inch SRM stage that are not available to the 260 inch SRM stage. The 156 inch SRM stages required to obtain comparable payload capability are 24 SRM stages for the AMLLV and 16 for the MLLV. This greater number of SRM's permit a larger number of potential vehicle configurations.

If the 156 inch SRM is transported by barge, it would then undergo the same operations as the 260 inch SRM stage. That is, the 156 inch motor would be manufactured, assembled into a stage and subjected to a stage checkout at the SRM manufacturer's facility. The 156 inch SRM stage would be shipped by barge and would remain on the barge at the launch site until required for assembly into the launch vehicle at the launch pad. The 156 inch SRM stages would then be handled and assembled to the vehicle in the same manner as described in Section 7.0 for the 260 inch SRM stage.

9.3 (Continued)

If the 156 inch SRM is transported by railroad, the method of assembly, checkout, and launch operations differ significantly from that described above. The 156 inch SRM segments and motor components would be assembled into a motor at the launch facility. After motor assembly, the motor would then be converted into a stage by the addition of stage components at the launch site, and subjected to a stage checkout. This transportation and launch operations concept is described in more detail below.

For the comparison of the 156 inch SRM stage and the 260 inch SRM stage, the 156 inch SRM was sized to deliver one half the thrust and contain one half the weight of propellant of the 260 inch SRM stage. This sizing permitted the 156 inch SRM to attach to the core stage at the forward skirt. A discussion of the sizing considerations for the 156 inch SRM is shown in Volume II (Half Size Vehicle (MLLV) Conceptual Design), Section 4.1.3.1. Figure 9.3.0.0-1 illustrates the comparison of the 156 inch SRM stage to the 260 inch SRM stage.

9.3.1 156 Inch Solid Propellant Motor Configuration

The 156 inch SRM stage will be of modularized construction. It will be handled and shipped in segments from the SRM manufacturer site to the launch complex. Assembly of the segments, motor components and stage components will be at the launch site. Special tooling and handling equipment will be provided for this activity. Each 156 inch motor will consist of a combustion chamber (fabricated from a forward closure, four interchangeable center segments, and an aft closure), a canted nozzle, a thrust vector control system, solid propellant fuel, an ignition system and a destruct system. The motor will be converted into a stage by the addition of on-board power sources, on-board test and checkout system, flight instrumentation, aft attachment structure, heat shield, forward attachment structure, nose cone and a solid motor separation system.

Thrust vector control will be obtained by a secondary fluid injection system or by a flexible seal thrust vectoring system. The ignition system will consist of a head end igniter with a safe and arm device, and dual explosive bridge wire (EBW) initiators. The propellant will be a mixture of polybutadiene-acrylic acid-acrylonitrile polymer, ammonium perchlorate, aluminum powder, and other additives. To insure bonding between the steel case wall and the propellant, a liner will be employed.

A brief description of the 156 inch SRM stage components are as follows:

Nose Cone - The aluminum nose cone will be bolted to the SRM forward attachment structure. This attachment structure in turn will be bolted to the SRM forward skirt. The nose cone exterior will be coated with an insulation material to protect it from the effect of aerodynamic heating. The nose cone will serve as an aerodynamic fairing, and as a housing for the flight equipment mounted in the nose cone area. The equipment in this area will include the staging rockets for separation, the safe and arm mechanism, the destruct system, the ignition system, and the electrical system.

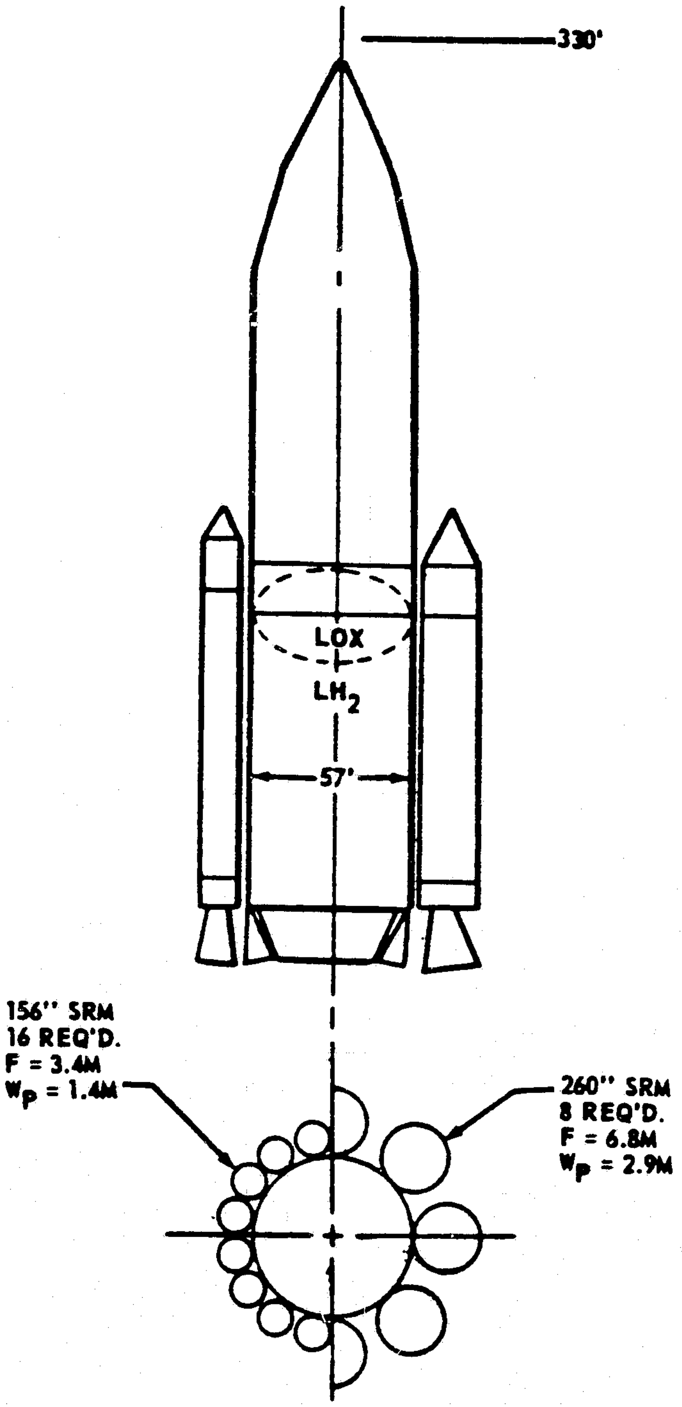


FIGURE 9.3.0.0-1 MLLV WITH 156 OR 260 INCH STRAP-ON STAGES

9.3.1 (Continued)

Forward Attachment Structure - The forward attachment structure which is mounted just below the SRM nose cone attaches the solid motor stage to the main stage of the vehicle. This HY 140 steel structure will be fabricated into a welded cylinder of a skin-frame-stiffener type construction. A thrust post will transmit the solid motor thrust into the core stage at station 1630.

156 Inch Combustion Chamber - The SRM case for the 156 inch motor will consist of a forward closure, four interchangeable cylindrical sections and an aft closure. Maraging steel case with an ultimate strength of 250,000 psi will be employed. The fore and aft closures will be hemispherical domes. The forward closure will have an opening for the ignition system, while the aft closure has an opening for the attachment of the nozzle. The segments will be tied together by a pinned clevice-tongue joint arrangement. The solid motor will have a short forward and aft cylindrical skirt. This skirt will be welded to the Y-ring which joins the cylindrical section of the case to the dome sections of the case.

Propellant Grain Configuration - The propellant grain configuration will be geometrically planned to produce a 50% regressive thrust-time history. (Thrust at the end of the SRM operation will be half the initial thrust level.) This will be achieved by providing a star point type grain configuration in the forward dome section of the motor which will have a large initial burning surface area. This will provide an initially high thrust level. As the SRM continues to burn, these star points burn away decreasing the burning surface area which results in a lower thrust level. The propellant located in the cylindrical segments and in the aft segment will be cast in a central perforated grain geometry configuration. By inhibiting the ends of these grain segments, the propellant surface area can be controlled to produce regressivity of thrust throughout SRM motor operation.

The nozzle for the 156 inch SRM will be fabricated from maraging steel with an ablative insulation liner insert. These nozzles will be canted to direct the SRM thrust through the forward attachment point between the SRM stage and the core vehicle. The nozzle divergence angle will be 17 1/2 degrees and extend to where the exit diameter of the nozzle will equal to the diameter of the case, i.e., 156 inches.

Thrust Vector Control System - Two thrust vector control systems are available for application to the 156 inch motor. One system is similar to that employed on the 260 inch SRM, and consists of a flexible seal which is an integral part of the nozzle, two servo actuators, hydraulic power system, and the hydraulic/electrical circuitry system. The alternative system is a liquid injection thrust vector control system (LITVC), which employes N_2O_4 as a liquid injectant into the nozzle. This deflects the SRM exhaust gases and produces the desired thrust deflection. If the LITVC system is employed, the N_2O_4 tank would be mounted along side the case. Either system is acceptable.

9.3.1 (Continued)

Aft Attachment Structure - The aft attachment structure will be fabricated from HY-140 steel. It will be a cylindrical skirt of a skin-stringer-frame construction. Staging rockets will be mounted on the aft skirt to provide part of the separation force required for SRM stage separation. The aft attachment structure will be bolted to the aft skirt of the SRM stage. The attachment structure will tie the aft end of the SRM stage to the core stage by means of a slip joint fitting. Tubular struts will tie the aft attachment structure to the core stage. These struts will react the torsional loads. Upon staging, shaped charges located in the struts, and the staging rockets will be ignited simultaneously. This aft end separation procedure, coupled with ignition of the staging rockets located in the nose cone, will provide sufficient lateral thrust to prevent the SRM stage from entering the core vehicle engine exhaust stream prior to achieving sufficient clearance for non-interference.

On-Board Test and Checkout System - The on-board test and checkout system on the 156 inch SRM stage will be similar to that described in Volume II of this final report (Section 4.3.7, On Board Test and Checkout System).

9.3.2 156-Inch SRM Stage Transportation System

Railroad facilities or barges may be employed to transport the 156 inch SRM segments and components. The following discussion concerns railroad transportation.

a. Segments, closures, igniters, and initiators will be loaded into environmental protective containers with associated support rings and monitoring equipment. The components will then be transported by common commercial carrier to a rail loading site. At the rail loading site, the components will be transferred to special, heavy capacity rail cars supplied by a commercial carrier. At this time, environmental control units and associated power sources will be installed and activated. These environmental control units will maintain the SRM components within the required temperature and humidity ranges during transportation. Aforementioned recorders to monitor shock, temperature, and humidity will also be utilized to support the transportation function.

b. Nozzles and nozzle extensions will be loaded in environmental containers with associated monitoring equipment, and are transported by commercial carrier to the rail loading site.

c. At the rail loading site the components will be loaded onto rail cars and environmental control equipment will then be activated.

d. Solid Rocket Motor trains will then be made up in any required quantity for transportation to the launch site. These trains will be scheduled into normal

9.3.2 (Continued)

freight service and can be expected to arrive at the launch site from the West Coast in 7 to 14 days. Monitoring of equipment and components will be required during this transportation phase.

e. All other associated hardware for SRM components will be either shipped directly from a manufacturing source directly to the launch site (utilizing standard commercial packaging and preservation methods) or from the SRM vendor, depending upon inspection and subassembly requirements.

The transportation requirements for one SRM are:

QUANTITY	NOMENCLATURE
2	Nozzle/Nozzle Extension Container
5	Segment/Closure Container
5	Temperature Control Unit
5	Diesel Engine Generator Set
5	SRM Protective Cover
1	Aft Closure Support Ring
4	Forward Closure & Segment Support Ring
5	Captive Rail Car
1	Aft Closure Hoisting Fixture
1	Forward Closure Hoisting Fixture
2	Adapter Closure
5	Truck, Tractor
5	Railway Car, Flat, Special Purpose
5	Semi-Trailer, Special Purpose
1	Crane, Mobile
5	Recorder, Temperature-Humidity
10	Recorder, Shock

If barges are used, the 156 inch SRM is converted into a stage at the SRM contractors facility, and loaded onto a barge. The transportation method, procedures, and equipment will be identical to the 260 inch SRM stage requirement as outlined in Section 6.0, except where diameter differences necessitate changes. The quantity of resources required for transportation must be doubled to obtain the same payload capability as with the 260 inch SRM stages.

9.3.3 156-Inch SRM Stage Operations Plan

Assuming the railroad transportation of 156 inch SRM motor is used, the 156 inch SRM will arrive at the KSC site in several major subassemblies, such as individual segments, forward and aft closures, nozzle assembly, skirt, heat shield, igniter assembly, TVC tank assemblies, and electric cable harness.

9.3.3 (Continued)

The inert components such as the TVC tank assemblies, nose cone sections, heat shield assembly, support skirt assembly and cable raceways will be moved to the Inert Component Building (ICB) for inspection, subassembly, checkout, leak testing and storage, before integration with the live rocket motor components in the Mobile Erection and Processing Structure (MEPS).

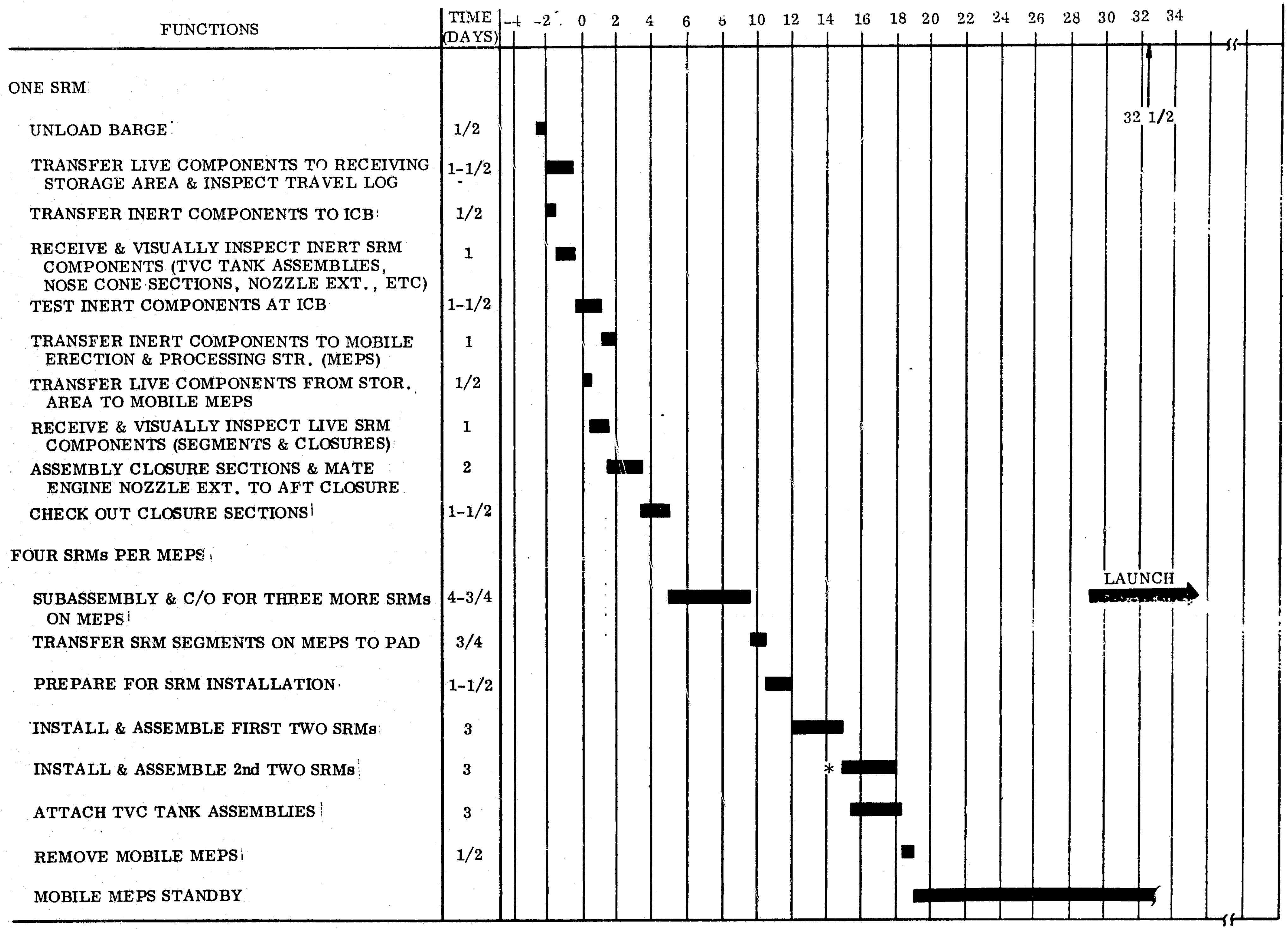
The live rocket motor components, such as the forward closures, aft closures, segments, and the igniter assemblies will be received at the Segment Storage Area for preliminary damage inspection. The SRM segments and closure assemblies will undergo receiving inspection, components installation and individual checkout in a new MEPS. The elements necessary for the complete assembly of the forward closure are the igniter assembly, nose cone section, destruct system, and instrumentation system components. The aft closure will be assembled into one unit consisting of the aft closure section, nozzle assemlby, support skirt assembly, nozzle exit cone extension, and heat shield. Subassembly is followed by checkout and testing. Upon completion, the preassembled SRM subassemblies may be either stored, or immediately transferred to the pad on the MEPS for assembly and integration with the liquid core vehicle. Two cranes, mounted on the MEPS, will be used to lift and attach the aft closure to the SRM aft support.

Figure 9.3.3.0-1 was prepared to time line the basic processing required for all 156 inch SRM stages, from receipt at the launch site to final assembly and integration with the main stage. Approximately one week is required to receive and inspect the SRM components, and to assemble the forward and aft closure subassemblies. As the maximum number of 156 inch SRM stages will be 16 for the MLLV, either 16 weeks will be required, or four crews will be required to decrease this time to four weeks. Four crews were selected to fully use the four MEPS required. With four MEPS, fourteen days will be required to transfer the 156 inch SRM stages to the launch pad and to install the SRMs. Thus a total of 42 days would be required for SRM operations with the segmented 156 inch SRM stages. The 260 inch SRM stages (which are delivered as completed stages) will require only 17 days.

9.3.4 156 Inch SRM Stage Facilities Required at the Launch Site

The facilities required at the launch site for the 156 inch strap-on stages are dependent upon the manufacturing, transportation, and launch operations concepts used.

If the 156 inch SRM stage is delivered as a complete assembled stage similar to the 260 inch SRM stage approach, then the launch facility requirements would be identical except for increased quantities of the tooling items. Since the 156 inch SRM's require twice as many motors as the 260 for the same payload, it is



*Add 3 working days to total time line for each additional pair of SRMs

FIGURE 9.3.3.0-1 SOLID ROCKET MOTOR (156 INCH SRM STAGE PROCESSING TIMES)

9.3.4 (Continued)

necessary to have increased quantities of the same items of tooling to reduce the time lines for assembly, checkout and launch of the flight vehicle.

If the 156 inch strap-on stage concept is that of fabrication and delivery of these segments to the launch site, assembly of these segments into the stage at the launch facility; then the facilities requirements are radically changed. The delivery of the segments will necessitate (1) that a large SRM and inert components building (ICB) be available, (2) a receiving and storage building be available for inspection and checkout of the subcomponents, (3) solid motor segment and component processing facilities, (4) solid motor segments transportation equipment, and (5) mobile erection and processing structures (MEPS) be available.

It is assumed that inspection and checkout operations for the major subassemblies can be accomplished in the MEPS and that the segments/closures, once processed, may be stored on board the MEPS until transferred to the pad for assembly and mating to the core stage. Once the 156 inch motors have been built into completed assemblies and converted into stages at the launch site, the procedure to be followed will be similar to that for the 260 inch SRM mating to the core vehicle. That is, the liquid main stage will be installed in the silo after all the SRM stages are in position and completed. The main stage will be supported on the launch pad by the SRM stages in either case,whether 156 inch or the 260 inch SRM strap-ons. The methods of attachment fore and aft will be similar.

Table 9.3.4.0-I lists the non-recurring costs of the facilities and equipment required especially for processing and handling of the 156 inch SRM stages at the launch site.

TABLE 9.3.4.0-I 156 INCH SRM STAGE FACILITY AND EQUIPMENT, NON-RECURRING COSTS

ITEM	QTY.	COST
Solid Motor Processing Facilities	4 sets	$ 23,708,000
Solid Motor Segment Transporter Equip.	4 sets	$ 4,952,000
Mobile Erection and Processing Structure (MEPS)	4 each	$ 34,124,000
TOTAL COST		$ 62,784,000

NOTE: Cost for new R. R. cars in lieu of GFE furnished: $1,031,040

END OF RESOURCE IMPLICATIONS DOCUMENT